Research Article

Integration of Telkom ISP and 3 LTE Using PCC Method to Improve Internet Connection Stability

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Abstract: This research focuses on improving internet connection stability at the Network Laboratory of JTIK, Faculty of Engineering, Universitas Negeri Makassar. The study aims to address the challenges of disruptions and instability frequently faced by users of Telkom WiFi in the laboratory, causing significant disruptions in internet activities. This instability is exacerbated by simultaneous internet usage, leading to network overload and bandwidth competition among users, ultimately reducing the overall network performance. As a solution, the research proposes the implementation of a network system that integrates Telkom ISP and 3 LTE using the PCC method. The system is equipped with a failover mechanism that automatically redirects the network connection to the active ISP when issues are detected. Additionally, the research categorizes users into admin lecturers and students, imposing bandwidth limitations specifically for students to prevent excessive network traffic. Three in-depth testing scenarios were conducted, demonstrating that the system smoothly redirects internet connections to the active ISP during issues, ensuring uninterrupted and effective internet access for users.

Keywords: Internet; PCC; ISP; Failover; Client; Network Traffic

Citation: M.F.I.P.Putra, J.M.Parenreng, M.Yahya, "Integration of Telkom ISP and 3 LTE Using PCC Method to Improve Internet Connection Stability", *Iota*, **2024**, ISSN 2774-4353, Vol.04, 02. https://doi.org/10.31763/iota.v4i2.728

Academic Editor : Adi, P.D.P

Received : March, 18 2024

Accepted : April, 29 2024

Published : May, 6 2024

1. Introduction

The Internet is a network that functions to connect one electronic medium with another. This communication network transfers data accurately and quickly through specific frequencies. The global standard for Internet usage itself has employed the Internet Protocol (IP) or Transmission Control Protocol (TCP). (AGUS, 2022). A computer network is a system consisting of computers designed to share resources (printers, CPUs), communicate (email, instant messaging), and access information (web browsers). (Barakabitze, 2020) A computer network is a collection of numerous computers that are separate but interconnected to perform their tasks (Mohamed et al., 2021).

According to Allan (2005), the Internet is a collection of computer networks connected, capable of reading and implementing various communication protocols, commonly known as IP and TCP. These protocols are simple specifications on how computers connect and interact. The internet network is not something new today. Almost every aspect of human life currently utilizes the internet. According to APJII, internet usage data in Indonesia for the period 2021-2022 reached 210 million users. This figure increased by 6.78% compared to the previous period, which had 196.7 million users. This has resulted in Indonesia's internet penetration rate reaching 77.02%. (Bayu, 2022).

Mikrotik RouterBoard is hardware similar to regular internet routers. This device can function as a local Internet Gateway by connecting and managing traffic flow from several Local Area Networks (LANs). Mikrotik can also manage computer network systems, with all network system configurations being centralized and organized. This enables Network Administration Lecturers to manage systems more easily and efficiently. Based on observations conducted in the JTIK network lab, the common issue faced by WiFi users in the JTIK network lab is that the Telkom WiFi network often goes down, causing interruptions in internet activities for WiFi users. Additionally, when the internet network

is used simultaneously, it can lead to network overload, resulting in users experiencing bandwidth contention, and the network received by users will not be optimal.

Based on previous research, such as the study conducted (Wijaya, 2015) titled "Bandwidth Management with HTB (Hierarchical Token Bucket) Method at State Junior High School 5 Semarang," the focus was on managing bandwidth using the HTB method. The advantage of this research is that the researcher was able to limit traffic at each level or classification, allowing unused bandwidth from higher levels to be used or borrowed by lower levels. However, the drawback of this research is that it only distributed bandwidth to 1 ISP or 1 network source, so if the ISP or network source experiences disruptions, all internet activities at SMP 5 Semarang will be interrupted.

Another study conducted by (Susianto, 2016) titled "Implementation of Queue Tree for Bandwidth Management Using Mikrotik Router Board" focuses on configuring bandwidth management with Mikrotik routers to maximize internet usage on each computer unit. The advantage of this research is that the researcher can adjust the amount of bandwidth needed by clients, ensuring fair and regular distribution of bandwidth to clients and maximizing the available bandwidth. However, the drawback of this research is that if the bandwidth allocated to client A is unused, it cannot be transferred to client B. Another study conducted by (Simpony, 2021) titled "Simple Queue for User and Bandwidth Management in Hotspot Networks Using Mikrotik" focuses on managing bandwidth based on the types of user profiles that will use internet services. The advantage of this research is that the researcher implements user management and bandwidth regulation methods, ensuring that all users receive the same bandwidth capacity. However, the drawback is that the researcher did not implement a Failover system in the study, so if the network connection experiences issues, internet activities will be interrupted. Based on the issues outlined in the background, the researcher proposes a solution by selecting a topic that will be titled "Integration of Telkom ISP and 3 LTE using Mikrotik PCC method ". This research focuses on dividing bandwidth for users based on user categories and also implements a Failover system. With this Failover system, internet users can still access the internet using a backup route if the main route encounters trouble.

2. Theory

Mikrotik is one of the vendors, both in hardware and software, that provides facilities for creating routers. One of them is Mikrotik RouterOS, which is an operating system specifically used to create a router by installing it on a computer. The facilities or tools provided in Mikrotik RouterOS are very comprehensive for building a reliable and stable router. Winbox is a utility used for connectivity and configuration of Mikrotik using MAC Address or IP Protocol. With Winbox, we can quickly and easily configure Mikrotik Router OS and Router Board using the GUI (Graphical User Interface) method. Winbox is built using Win32 binary but can be run on Linux and macOS using Wine. All Winbox functions are designed and made to be as close as possible to console functions.(Khafif & Semarang, 2021)

The Internet is short for Interconnected Networking, which in Indonesian means a network of interconnected computers within several network frameworks. The Internet is a computer network that connects the entire world without recognizing territorial boundaries, laws, and cultures (Supardi, 2019). Bandwidth is a measure indicating how much data can pass through a connection over a network. This term originates from the field of electrical engineering, where bandwidth indicates the total range or spread between the highest and lowest signal frequencies on a communication channel (band). (Susianto, 2016). Bandwidth serves as a benchmark for the speed of information transfer through a channel. The larger the bandwidth, the more information can be sent.

Bandwidth management is a network management technique aimed at providing fair and satisfactory network performance. Bandwidth management is also used to ensure adequate bandwidth to meet data and information traffic needs and to prevent competition between applications. Bandwidth management is essential for multi-service networks, as the increasing number and variety of applications that a network can serve will affect the use of links in the network. Links must be able to handle user demands for applications even during congestion. (Ajika, 2016)

Bandwidth management is one method for network management that aims to provide fair network performance and make users comfortable. This method is also used to ensure sufficient bandwidth to meet data and information needs and also to avoid competition between computers. Bandwidth management is essential for multi-service networks because the more applications a network can serve, the greater the impact of using links in the network. Links must be able to handle user requests for applications even during latency. (Novrianda, 2022)

A hotspot is one form of utilizing wireless technology in public locations such as libraries, campus areas, parks, and others. The term "hotspot" refers to an area where people or users can access the internet, as long as they use a device with Wi-Fi capabilities, such as a PC, laptop, or another wireless-enabled device, without the need for a cable connection. Another definition of a hotspot is an area where a client can connect to the internet wirelessly or without cables from a PC, laptop, notebook, or gadget such as a mobile phone within a range of approximately several hundred meters depending on the strength of the frequency or signal. (Syahputra, 2022).

Failover is one method for adding connections, whereby if the main link or primary connection goes down, the backup link or secondary connection will automatically switch to maintain a connection.(Rukmana & Suhendi, 2023). Load Balancing using the PCC concept is a technique for distributing traffic load on two or more connection paths to be balanced, ensuring optimal traffic flow, maximizing throughput, minimizing response time, and avoiding overload on any one connection path. The advantage of the PCC method is its ability to specify a gateway for each data packet that is still related to the data previously passed through one gateway. (Oktivasari & Sanjaya, 2015)

The PCC method is one of the methods that can be used in load balancing, with PCC used to group connection traffic passing through the router into several groups. As a result, the router will recognize the gateway route passed at the initial connection traffic and the subsequent packets still related to the initial connection. (Triyono, 2019). In 2016, a study conducted by (Susianto, 2016), titled "Implementation of Queue Tree for bandwidth management using Mikrotik Router Board." In this study, the method used is the Queue Tree. The background addressed in this research is how to obtain bandwidth with equal or uniform size without disrupting the bandwidth of other users/hosts. The solution offered by the researcher in this study is to manage bandwidth using a queue tree on a Mikrotik router. The difference from previous research is the different methods used.

In 2017, a study was conducted by (Firdaus, 2017), titled "Comparison analysis of load balancing performance between ECMP (Equal Cost Multi-Path) and PCC (Per Connection Classifier) methods on Mikrotik RouterOS." This study discusses the advantages and disadvantages of ECMP and PCC methods. This study concludes that the PCC method produces better throughput than the ECMP method. The PCC method has better resilience when network disruptions occur, and the ECMP method produces better RTT than the PCC method.

Based on previous research conducted, the author proposes integrating Telkom ISP and 3 LTE using the Mikrotik PCC method. The advantage of this research compared to previous studies is that the researcher uses 2 ISPs or 2 network sources and combines them to become 1 network that will be used by users. In this study, the researcher also implements a Failover system so that if one path has problems in the user network, they can still access the internet, and this research also implements bandwidth management for each user. This method is applied to ensure that the connection and internet speed obtained by users will be stable and the internet connection of users will not be affected by the internet usage of other users.

3. Method

In this study, the researcher employed an Experimental research design by experimenting with Mikrotik on how to integrate 2 ISPs using the Mikrotik PCC method to enhance internet connection stability. Additionally, a Failover system was implemented. In Figure 1, the network schema in the Laboratory Network Scheme of the Department of Informatics Engineering and Computer Science, UNM, still relies on 1 ISP as the internet source and has not undergone bandwidth management. Consequently, if users utilize the network simultaneously, they will experience bandwidth contention, leading to disrupted network access. The Wi-Fi network in the Laboratory Network Scheme of the Department of Informatics Engineering and Computer Science, UNM, also relies on a single network source for each Wi-Fi, requiring users to manually switch to another Wi-Fi network if they encounter issues.

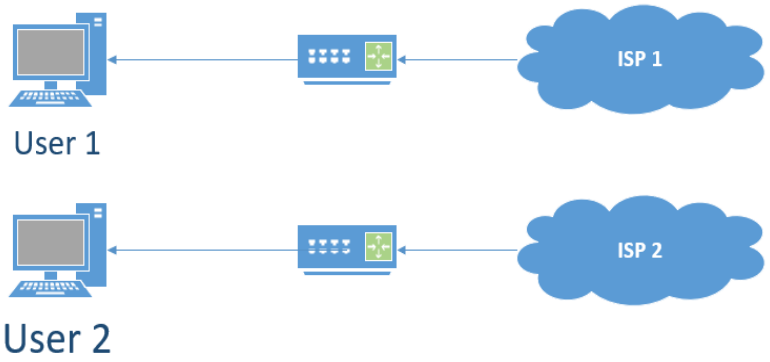

Figure 1. The network schema for the Network Lab of the Department of Informatics and Computer Engineering at UNM

In Figure 2, a proposed network schema is presented, where bandwidth management has been implemented. The bandwidth load for each user will be allocated based on their needs and user type, ensuring a more stable network experience for users. Users are divided into two categories: Priority Users and Student Users. Priority Users, typically faculty members, are allocated the highest bandwidth capacity among all user types. On the other hand, Student Users, who are students in the Department of Informatics Engineering and Computer Science lab, receive a lower bandwidth capacity compared to Priority Users. Additionally, in this study, bandwidth management was conducted using the PCC algorithm. This algorithm is utilized to combine more than one ISP, allowing automatic switching to another ISP if one experiences issues or network disruptions. As a result, users do not need to manually reconnect to the network.

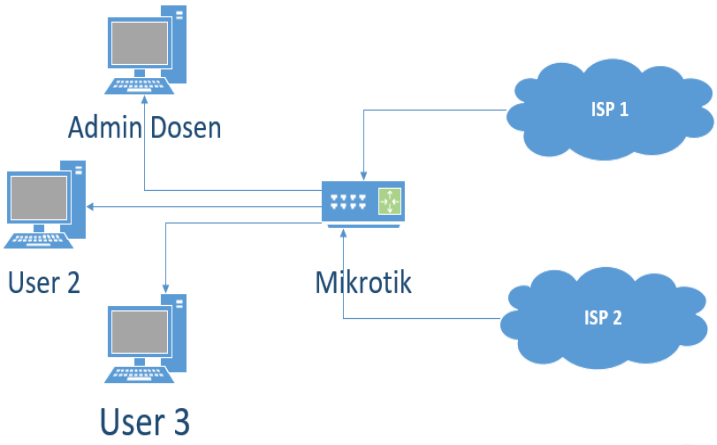

Figure 2. Research Network Scheme

This research implements three testing scenarios. The first scenario activates both ISPs, the second scenario deactivates Telkom ISP and activates 3 LTE ISPs, while the third scenario activates Telkom ISP and deactivates 3 LTE ISPs. During the testing and data collection phase, the researcher will conduct tests and measurements of the internet speed to assess the quality of internet service. At this stage, the researcher will perform speed tests to determine the bandwidth received by users and conduct delay time tests to assess the delay speed experienced by users.

The workflow of the research system involves users connecting their devices to the Mikrotik Wi-Fi network. Then, Mikrotik will route using PCC and apply the Failover method. The system will then decide whether to use Telkom ISP or 3 LTE ISP. After that, the system will determine whether the user is a priority user or a visitor. If the user logs in using a Student account, the system will categorize the user as a Student User. Subsequently, the system will limit the download bandwidth to 5 MB/s and the upload bandwidth to 5 MB/s. If the user logs in using an Admin account, the system will categorize the user as a Priority User. After selecting the user category, the user can access the internet using the Integrated Telkom and 3 LTE ISP Network Using the PCC Method to Improve Internet Connection Stability. The workflow of this system can be seen in Figure 3, the network system flowchart.

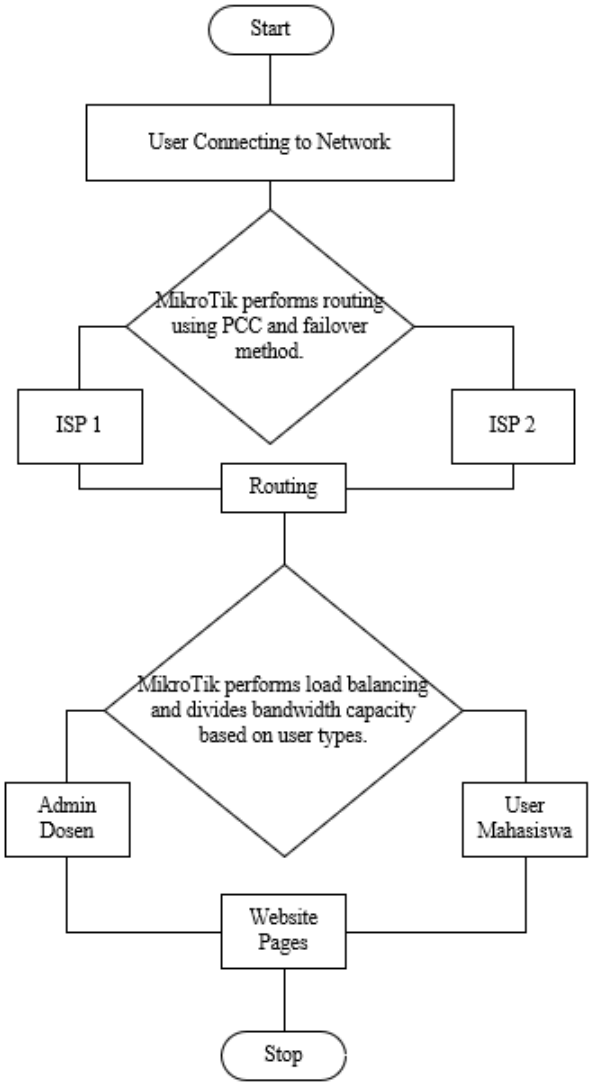

Figure 3. Flowchart System

In this research, bandwidth management is also conducted using the PCC algorithm. This algorithm is used to combine more than one ISP, so that if one ISP experiences disruption or network problems, the other ISP will automatically connect, eliminating the need for users to manually reconnect the network.

The research involves several main stages. First, is the Potential & Problem stage where issues are raised in the background and formulated for system development. Then, in the Needs Analysis stage, the researcher conducts research needs analysis by gathering information related to Mikrotik from relevant studies. Next, in the Literature Review stage, the researcher gathers literature data related to the research entitled "Integration of Telkom ISP and 3 LTE Using the PCC Method to Improve Internet Connection Stability." The Design & System Development Stage involves creating flowcharts that explain how the system works. System Testing involves Mikrotik configuration, PCC testing, bandwidth allocation based on user types, and activity testing. Subsequently, in the Data Collection Method stage, the researcher conducts internet speed testing and measurement to assess internet service quality in integrating Telkom ISP and 3 LTE using the PCC method to improve internet connection stability. Finally, the Revision stage involves adjustments and improvements if there are errors or discrepancies in the system that cause the device to not function as described earlier.

4.Result and Discussion

4.1 Bandwidth Data

Based on Table 1 Bandwidth Data, the bandwidth data in Table 1 shows that the system has successfully managed the bandwidth for the Admin Lecturer client. The Admin Lecturer obtained 90.31 Mb/s download speed and 19.59 Mb/s upload speed. Meanwhile, for the student users, on average, they received a bandwidth of 4.75 Mb/s for downloads and 4.31 Mb/s for uploads. Based on the test results shown in Table 1, it can be concluded that the bandwidth management system has worked successfully. Admin Lecturer client received unrestricted bandwidth, while the student client's bandwidth did not exceed 5 Mb/s for downloads and uploads.

Table 1. Data Bandwidth

User Type	Bandwidth received up to (mb/s)	
	TX	RX
User 1 Lecturer Admin	90.31 Mb/s	19.59 Mb/s
User 2 Student 1	4,83 Mb/s	4,03 Mb/s
User 3 Student 2	4,76 Mb/s	4,74 Mb/s
User 4 Student 3	4,73 Mb/s	4,19 Mb/s
User 5 Student 4	4,68 Mb/s	3,98 Mb/s
User 6 Student 5	4,79 Mb/s	4,63 Mb/s
Average student bandwidth	4.75 Mb/s	4.31 Mb/s

4.2 PCC and Failover Testing Data

In this stage, the researcher will conduct testing on the Failover system that has been implemented to determine whether it functions properly or not. During this test, the researcher will activate both ISPs and observe the system's response. Then, the researcher will deactivate one of the ISPs and observe whether the system continues to operate or not.

Table 2. PCC Testing Condition

Testing	ISP Condition		ISP used	
	ISP Broadband_UNM	ISP 3 LTE	ISP Broadband_UNM	ISP 3 LTE
.Ping	Active	Active	✓	
Ip src: 10.20.30.254	Off	Active		✓
Ip Dst: 142.251.10.102	Active	Active	✓	
Download	Active	Active	✓	✓
Ip src: 10.20.30.254	Off	Active		✓
Ip dst: 74.125.200.94	Active	Off	✓	
Streaming Youtube	Active	Active	✓	
Ip src: 10.20.30.254	Off	Active		✓
Ip dst: 209.197.3.8	Active	Off	✓	
Speed Test	Active	Active	✓	✓
Ip src: 10.20.30.254	Off	Active		✓
Ip dst: 36.86.63.182	Active	Off	✓	

Based on the results of the tests in Table 2 PCC Condition Testing indicates that when conducting ping tests with both ISPs activated, the system's response shows that the network system prioritizes using the ISP Telkom connection. Subsequently, in the second scenario where the researcher disconnects the ISP Telkom connection, the system's response shows that it successfully redirects the connection from the ISP Telkom to the ISP 3 LTE network. In the third testing scenario, where the researcher disconnects the ISP 3 LTE connection, the system responds by redirecting the network connection back to the ISP Telkom.

The download test results in Table 2 for the PCC condition testing show that when the researcher conducts download activities across the three testing scenarios, the system responds differently. In the first scenario, where both ISPs are activated, the system utilizes both ISP connections. In the second scenario, where the ISP Telkom connection is deactivated while the ISP 3 LTE remains active, the system successfully switches the connection from the ISP Telkom to the ISP 3 LTE network. Similarly, in the third scenario, where the researcher disconnects the ISP 3 LTE connection while keeping the ISP Telkom active, the system responds by redirecting the internet connection from the ISP 3 LTE to the ISP Telkom.

In the subsequent stage, the researcher conducted streaming tests across the three testing scenarios. The results in Table 2 of the PCC testing show that in the first testing scenario, with both ISPs activated, the network system selects the ISP Telkom connection as the primary route. In the second scenario, where the ISP Telkom connection is disconnected, the system redirects the connection from the ISP Telkom to the ISP 3 LTE network. In the last scenario, when the ISP 3 LTE connection is disconnected and the ISP Telkom is activated, the system switches the connection from the ISP 3 LTE to the ISP Telkom.

Speed test measurements or bandwidth assessments were also conducted across the three different scenarios: activating both ISPs, deactivating the ISP Telkom and activating the ISP 3 LTE, and deactivating the ISP 3 LTE and activating the ISP Telkom for the Admin Lecturer user. The results in Table 2 of the PCC testing show that when conducting speed tests in the first scenario, activating both ISPs, the system utilizes both ISP connections to ensure users receive stable and substantial bandwidth. In the second scenario, deactivating the ISP Telkom, the system switches the internet connection from the ISP Telkom to the ISP 3 LTE. Similarly, in the third scenario, deactivating the ISP 3 LTE, the

system responds by redirecting the internet connection from the ISP 3 LTE to the ISP Telkom.

The following illustrates the system's behavior when one of the ISPs experiences a disconnection. In this stage, the researcher will watch a streaming video on the YouTube website, specifically on the Mario Iroth channel. After the video streaming begins, the researcher will disconnect one of the ISPs, namely, the ISP Telkom. For more detailed information, please refer to the image in Figure 4 for the YouTube testing.

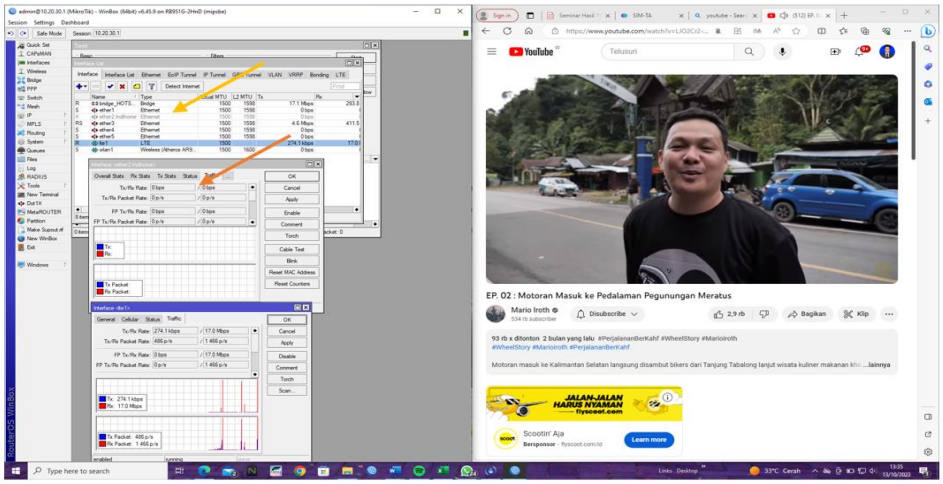

Figure 4. YouTube Testing with ISP Broadband_UNM Off

In Figure 4, it can be seen that the ISP Telkom is deactivated, indicated by the orange arrow, and at the yellow arrow, it can be observed that there is no internet data flow on the ISP Telkom. When this occurs, the system redirects the connection from the ISP Telkom to the ISP 3 LTE network. Furthermore, the researcher will disconnect the connection to the ISP 3 LTE. For clearer information, please refer to the YouTube testing in Figure 5.

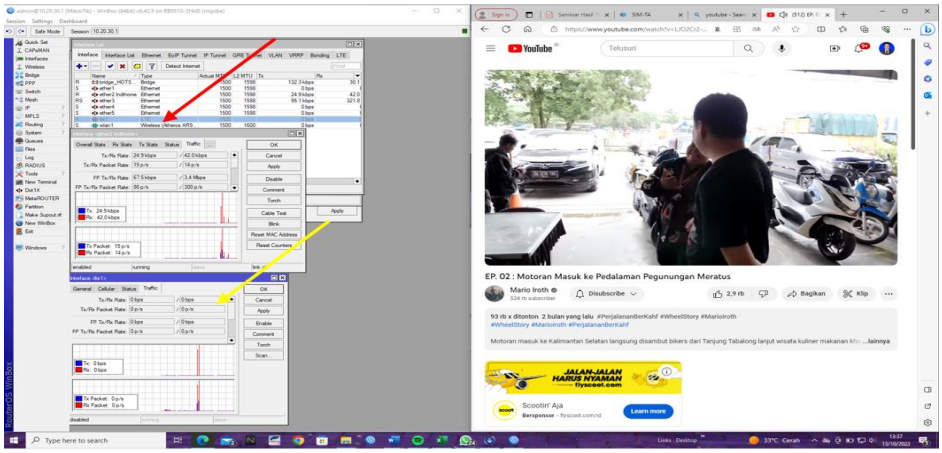

Figure 5. YouTube testing with ISP 3 inactive

Based on Figure 5, it can be seen that when ISP 3 LTE is deactivated, as indicated by the red arrow, there is no data flow on the ISP 3 LTE, as shown by the yellow arrow. After the disconnection of the connection to one of the ISPs, it turns out that the video streaming condition continues smoothly without interruption and a decrease in video quality. Based on the test results in Figure 5, it can be concluded that the gateway transition from ISP Telkom to ISP 3 LTE automatically operates well. Similarly, when the gateway transition from ISP 3 LTE to ISP Telkom occurs, it also functions automatically without issues.

The PCC and failover testing for the Admin Lecturer were conducted for one month, involving one PC for the Admin Lecturer and utilizing three scenarios. The first scenario involved activating both ISPs, the second scenario involved deactivating ISP Telkom, and the third scenario involved deactivating ISP 3 LTE. This research was conducted over one month, taking place on Saturdays and Sundays, as well as from Mondays to Sundays. For more detailed data, please refer to Table 3 PCC and Failover Testing for 1 Month for Admin Lecturer in Table 3.

Table 4. PCC and Failover Testing 1 Month Admin Lecturer

Week	Scenario						
	Admin Lecturer	**ISP Broadband UNM and 3 LTE Active**		**ISP Broadband UNM OFF**		**ISP 3 LTE OFF**	
	Day	**RX**	**TX**	**RX**	**TX**	**RX**	**TX**
1	Saturday	90.31	19.59	34.56	15.78	61.40	13.31
	Sunday	90.86	19.68	18.59	8.34	85.31	17.62
2	Saturday	87.31	20.50	18.88	6.79	72.06	19.68
	Sunday	87.27	19.59	19.69	9.48	85.36	16.15
3	Saturday	87.20	19.65	17.90	14.51	86.46	19.59
	Sunday	86.73	25.54	20.76	6.04	80.50	20.86
4	Saturday	91.00	19.81	36.80	10.47	61.85	13.82
	Sunday	86.40	24.82	10.51	9.51	81.77	22.06
5	Monday	92.20	19.83	22.73	12.53	75.45	19.80
	Tuesday	90.07	21.06	28.58	14.3	74.41	20.40
	Wednesday	81.73	26.06	20.27	11.10	61.81	15.82
	Thursday	81.70	25.73	07.67	11.70	80.14	18.27
	Friday	81.78	26.71	19.36	10.33	72.43	15.38
	Saturday	91.67	31.82	16.24	12.75	75.7	19.73
	Sunday	91.70	21.80	11.66	10.49	51.9	15.83
	Average	**81.86**	**22.81**	**20.28**	**10.94**	**73.77**	**17.88**

Based on the test results in Table 3 PCC and Failover 1 month Admin Dosen Testing indicates that in the first scenario, where both ISPs were used, users obtained an average download bandwidth of 81.86 Mb/s and an upload bandwidth of 22.81 Mb/s. In the second scenario, where ISP Telkom was deactivated, users averaged a download bandwidth of 20.28 Mb/s and an upload bandwidth of 10.94 Mb/s. Lastly, in the third scenario, where ISP 3 LTE was deactivated, users obtained a download bandwidth of 73.77 Mb/s and an upload bandwidth of 17.88 Mb/s. Table 5 is the table of results, along with the averages from the PCC and failover testing for the Mahasiswa, conducted over one month on Saturdays, Sundays, and from Mondays to Sundays, using three different scenarios and involving five student PCs.

Table 5. PCC and Failover Testing 1 month for Student Users

Week	Students	Scenario					
		ISP Broadband_UNM and ISP 3 LTE ON		ISP Broadband_UNM OFF		ISP 3 LTE	
	Day	RX	TX	RX	TX	RX	TX
1	Saturday	4.75	4.31	4.22	3.03	4.35	3.65
	Sunday	4.66	4.42	3.92	3.02	4.5	3.93
2	Saturday	4.81	4.2	3.97	3.41	4.52	3.76
	Sunday	4.7	4.52	3.5	2.9	4.51	3.6
3	Saturday	4.74	4.37	3.89	2.71	4.41	4.16
	Sunday	4.6	4.32	3.94	3.03	4.58	4.19
4	Saturday	4.59	4.32	3.54	2.99	4.46	3.64
	Sunday	4.69	4.69	3.86	3.16	4.47	3.86
5	Monday	4.47	4.24	4.13	3.24	4.07	3.55
	Tuesday	4.73	4.16	4.51	3.03	4.59	3.74
	Wednesday	4.7	4.54	4.37	3.6	4.4	3.47
	Thursday	4.73	4.13	4.13	3.19	4.48	3.51
	Friday	4.78	4.35	4.11	3.3	4.42	3.46
	Saturday	4.78	4.3	3.97	3.35	4.44	3.87
	Sunday	4.61	4.26	4.11	3.14	4.54	3.55
Average		**4.68**	**4.34**	**4.01**	**3.14**	**4.44**	**3.72**

Based on the test results in Table 4 PCC and failover 1 Month Testing of The Mahasiswa User, conducted on Saturdays, Sundays, and from Mondays to Sundays, it can be observed that in the first scenario, where both ISPs were used, users obtained an average download bandwidth of 4.56 Mb/s and an upload bandwidth of 4.35 Mb/s. In the second scenario, where ISP Telkom was deactivated, users averaged a download bandwidth of 3.81 Mb/s and an upload bandwidth of 3.18 Mb/s. Lastly, in the third scenario, where ISP 3 LTE was deactivated, users obtained a download bandwidth of 4.38 Mb/s and an upload bandwidth of 4 Mb/s.

4.3 Delay Time User 1 Month Data

Here is a table of the results, along with their averages, from the delay calculations conducted over one month using three scenarios. The first scenario activates both ISPs, the second scenario deactivates ISP Broadband_UNM and activates ISP 3 LTE, and the third scenario activates ISP Broadband_UNM while deactivating ISP 3 LTE, all involving six client PCs. For more detailed data, please refer to the Table 6.

Table 6. Month Delay Time Testing

Week	Day	Scenario					
		ISP Broadband_UNM and ISP 3 LTE ON		ISP Broadband_UNM OFF		ISP 3 LTE OFF	
		Delay (ms)	Index	Delay (ms)	Index	Delay (ms)	Index
1	Saturday	54	4	65	4	58	4
	Sunday	81	4	89	4	88	4
2	Saturday	75	4	78	4	76	4
	Sunday	70	4	77	4	75	4
3	Saturday	71	4	75	4	78	4
	Sunday	72	4	76	4	74	4
4	Saturday	50	4	59	4	54	4
	Sunday	62	4	68	4	65	4
5	Monday	49	4	67	4	55	4
	Tuesday	47	4	73	4	65	4
	Wednesday	49	4	72	4	64	4
	Thursday	49	4	73	4	77	4
	Friday	44	4	68	4	62	4
	Saturday	46	4	72	4	64	4
	Sunday	47	4	69	4	68	4
Average		**58**	**4**	**72**	**4**	**68**	**4**

Based on the test results in Table 6 Month Delay Time Testing, indicates that users fall into the category 4, which means it's in the very good category. The largest delay time observed was 73 ms when ISP Broadband_UNM was deactivated, and in the scenario where ISP 3 LTE was deactivated, users experienced an average delay time of 71 ms with the lowest delay time recorded at 67 ms when both ISPs were active.

5. Conclusions

The research has successfully achieved several main objectives. Firstly, the goal of stabilizing the network and reducing the risk of bandwidth overload was achieved by implementing bandwidth restrictions on users, integrating two ISPs, and implementing a failover system to ensure smooth network operation if one ISP encounters issues. Test results conducted over a month indicate that the system operates well. When both ISPs are active, student users receive an average download speed of 4.56 Mb/s and an upload speed of 4.35 Mb/s. When ISP Telkom is deactivated, download speeds decrease to 3.81 Mb/s and upload to 3.18 Mb/s, while deactivating ISP 3 LTE results in download speeds of 4.38 Mb/s and upload speeds of 4 Mb/s. Bandwidth limitations successfully maintain speeds below 5 Mb/s. Additionally, the PCC and failover systems operate without significant decrease when ISPs are deactivated, with an average delay time of 58ms when both ISPs are active, 72ms when ISP Telkom is deactivated, and 68ms when ISP 3 LTE is deactivated.

Acknowledgments: The author would like to thank the Department of Informatics and Computer Engineering Faculty of Engineering Universitas Negeri Makassar, which supports the completion and publication of this research.

Author contributions: All authors are responsible for building Conceptualization, Methodology, analysis, investigation, data curation, writing—original draft preparation, writing—review and editing, visualization, supervision of project administration, funding acquisition, and have read and agreed to the published version of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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