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Bandwidth Management Analysis Using Hierarchical Token Bucket (HTB) with MikroTik on the Network of Lisna Clinic YPK PLN Makassar 01

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ABSTRACT

This study aims to implement bandwidth management using the Hierarchical Token Bucket (HTB) method on a MikroTik RB 941 router, utilizing the Simple Queue technique at YPK PLN Clinic Makassar 01. Internet network stability is crucial for several staff members who have experienced issues with poor connectivity. The analysis of internet usage at the clinic reveals the distribution of network access across multiple servers, namely: Cluster 1, which includes the Admin Room, Laboratory, and Pharmacy; Cluster 2, covering the Registration Room, Medical Records Room, and Nurse Station; Cluster 3, comprising the General and Dental Clinics; and Cluster 4, consisting of the Emergency Room and Lobby area. Based on bandwidth requirements analysis, the maximum bandwidth allocation is set as follows: the main server requires 40 Mbps, Cluster 1 receives 10 Mbps, Cluster 2 receives 15 Mbps, Cluster 3 receives 8 Mbps, and Cluster 4 receives 7 Mbps. Performance evaluation was conducted by measuring throughput, delay, jitter, and packet loss. The test results indicate improved computer network performance at YPK PLN Clinic Makassar 01 after implementing the HTB method, with average throughput increasing from 524 Kbps to 1649 Kbps, packet loss remaining at 0.00%, delay decreasing from 122.567 ms to 40.173 ms, and jitter dropping from 122.564 ms to 40.452 ms. These findings demonstrate a significant improvement across all parameters following the application of HTB.

I. Introduction

The internet is a communication network system that connects multiple computers without limitations of time or location, thereby creating a global network community. This concept originates from the term interconnection network [1], [2], which refers to the interconnection of computer networks to access the internet [3], [4]. Klinik Lisna YPK PLN Makassar 01, located on Hertasning Raya Block B, employs 34 staff members and subscribes to Telkomsel's INDIHOME internet service with a bandwidth package of 40 Mbps. However, during daily operations, the clinic often experiences delays caused by unregulated and excessive internet traffic, resulting in slow internet access, particularly when using SIM LISNA and IZI KLAIM applications—especially during peak hours between 10:00 AM and 12:00 PM. These issues highlight the critical need for bandwidth management through the Hierarchical Token Bucket (HTB) method to stabilize the internet connection at the clinic.

This study aims to implement bandwidth management using the HTB method on a MikroTik RB 941 router, utilizing the Simple Queue technique at Klinik YPK PLN Makassar 01 [5], [6]. It evaluates the effectiveness of the HTB method in managing and controlling network traffic flow, as well as measuring how well it regulates and limits bandwidth usage efficiently.

Operational delays often occur at Klinik Lisna YPK PLN Makassar 01 due to congested and unbalanced internet traffic, which significantly hampers internet access—particularly during critical business hours when using the SIM LISNA and IZI KLAIM systems. The absence of an effective bandwidth management system further aggravates this condition, underlining the urgency for a reliable and efficient bandwidth control solution [7], [8].

Previous studies have explored bandwidth management using the HTB method, such as research conducted at PT Bukit Energi Servis Terpadu, located at STMIK Asia Malang [8], [9]. Additionally, another study investigated the combination of HTB and Quality of Service (QoS) implemented in an RT/RW Net network in Perumahan Prasanti 2, near Qamarul Huda University, Badaruddin [10], [11]. This study differs from the previous ones in that it focuses on HTB implementation at Klinik YPK PLN Makassar 01 with a specific configuration using MikroTik RB 941 and the Simple Queue technique. Moreover, this research measures overall network performance improvements using four parameters: throughput, delay, jitter, and packet loss, which have not been widely explored in a clinical setting.

This study proposes the implementation of the Hierarchical Token Bucket (HTB) method with a specific configuration on MikroTik RB 941 and Simple Queue as a solution to bandwidth management issues at Klinik YPK PLN Makassar 01 [12]. This method is expected to provide better control over network traffic flow and optimize bandwidth usage, thereby reducing delays and improving internet access during peak hours.

The implementation of the HTB method with MikroTik at Klinik Lisna YPK PLN Makassar 01 is expected to stabilize internet connectivity, reduce access latency, and improve bandwidth utilization efficiency. This research offers a novel contribution to network management in clinical environments and provides valuable references for further studies in the field of bandwidth management..

II. Method

The stages of this research are as follows:

Figure 1. Research flow

A. Field Observation

At this stage, the researcher submitted a formal request to conduct research at the designated location, Klinik Lisna YPK PLN Makassar 01. The researcher carried out direct observation on-site to gain a clear understanding of the problems to be studied.

B. Problem Identification

The researcher identified the issues occurring at the research site, with the aim of understanding the root causes and determining appropriate solutions to address or resolve the problems observed in the field.

C. Data Collection

In this stage, data were collected through interviews. The data gathered included the network topology at Klinik Lisna YPK PLN Makassar 01, bandwidth allocation, and specifications of the equipment used in the clinic's network infrastructure.

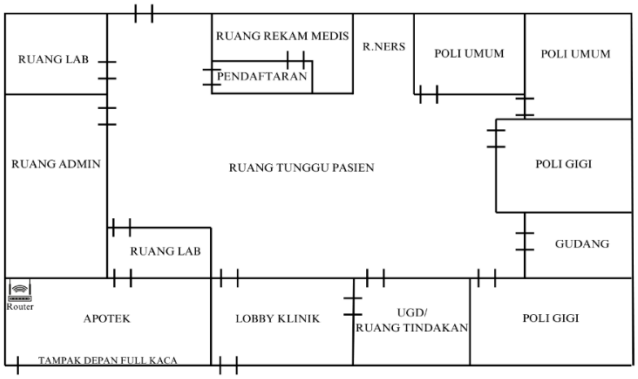

Figure 2. Floor Plan of Klinik Lisna YPK PLN Makassar 01

Figure 2 presents the floor plan of Klinik Lisna YPK PLN Makassar 01, showing the placement of a single router located at the end of the pharmacy room. This strategic location allows the router to cover the entire clinic area, ensuring wide and stable network coverage throughout the facility

D. Data Collection

At this stage, data collection involved conducting several network performance tests, including bandwidth testing, throughput measurement, delay testing, jitter evaluation, and packet loss analysis. These tests were performed using standard network monitoring procedures and tools [13].

E. Comparative Analysis Before and After Applying the HTB Method

Once the data for bandwidth, throughput, delay, jitter, and packet loss were collected, the next step was to compare the results before and after the implementation of the HTB method. The results of this comparison are presented in tabular form to clearly illustrate the differences and improvements observed after optimization.

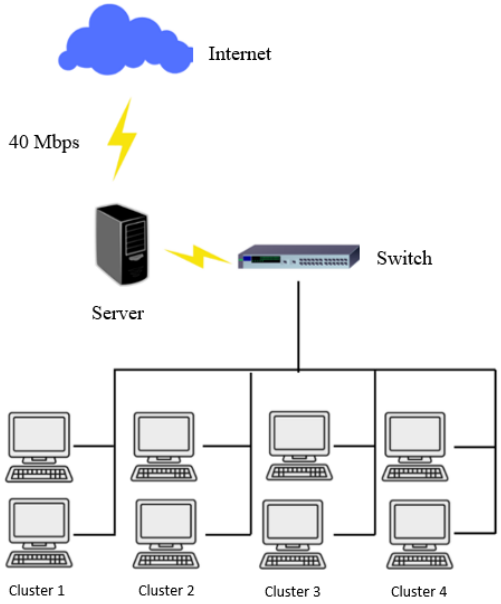

Figure 3. Network Topology of Klinik Lisna YPK PLN Makassar 01 Before and After Applying HTB

Figure 3 illustrates the network topology of the clinic service area prior to the implementation of bandwidth management using the Hierarchical Token Bucket (HTB) method [9], [14]. Internet access is provided through the INDIHOME service, with a total bandwidth capacity of 40 Mbps. The network is divided into several clusters:

- Cluster 1: Covers the Admin Room, Laboratory, and Pharmacy.
- Cluster 2: Includes the Registration Room, Medical Records Room, and Nursing Room.
- Cluster 3: Consists of the General Clinic and Dental Clinic areas.
- Cluster 4: Encompasses the Emergency Room (UGD) and the clinic lobby.

Bandwidth is distributed to client computers through a switch. After the implementation of bandwidth management using the HTB method, a MikroTik RB941 router was added to enable HTB configuration, as shown in **Figure 4**.

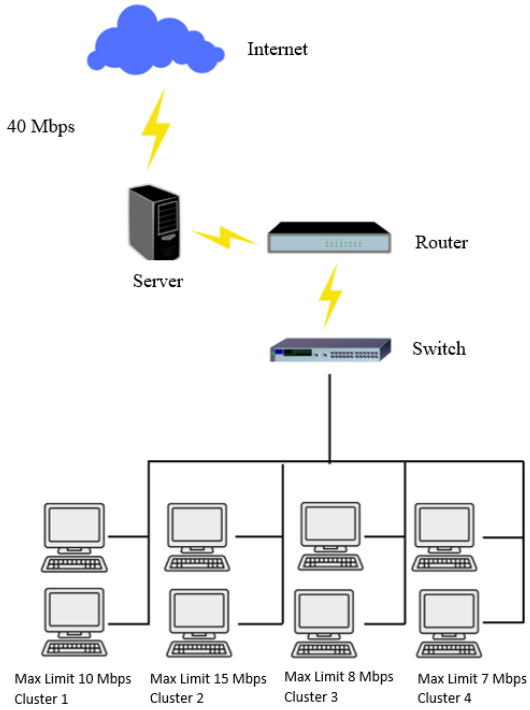

Figure 4. Network Topology of the Clinic After Implementing HTB

Figure 3 shows the initial network topology in the clinic's service area before the implementation of bandwidth management using the Hierarchical Token Bucket (HTB) method [15], [16]. The internet network used was provided by INDIHOME with a bandwidth capacity of 40 Mbps, which was distributed via a switch to client computers. The network was divided into several clusters: Cluster 1 covered the Admin Room, Laboratory, and Pharmacy; Cluster 2 included the Registration Room, Medical Records Room, and Nursing Room; Cluster 3 included the General Clinic and Dental Clinic; and Cluster 4 included the Emergency Room and the clinic lobby. After implementing bandwidth management using HTB, a MikroTik RB941 device was added for HTB configuration, as shown in **Figure 4**.

The testing scenarios were carried out in various clinic rooms over the course of eight days [17]. In Scenario 1, data collection was conducted in the Admin Room and Pharmacy from 10:00 a.m. to 12:00 p.m. Data was collected in three sessions: the first session from 10:15 to 10:30, the second session from 10:45 to 11:00, and the third session from 11:45 to 12:00. The parameters measured included throughput, delay, jitter, and packet loss.

In Scenario 2, data collection was conducted in the Registration Room and Nursing Room from 1:00 p.m. to 3:00 p.m. The data was collected in three sessions: the first session from 1:00 to 1:15, the second session from 1:45 to 2:00, and the third session from 2:45 to 3:00. The parameters measured were the same: throughput, delay, jitter, and packet loss.

In Scenario 3, data collection was conducted in the Dental Clinic, General Clinic, Emergency Room, and clinic lobby from 4:00 p.m. to 6:00 p.m. Data was collected in three sessions: the first session from 4:00 to 4:15, the second session from 4:45 to 5:00, and the third session from 5:45 to 6:00. The parameters measured also included throughput, delay, jitter, and packet loss. This data collection aimed to evaluate the network performance and to measure the specified parameters throughout the testing period.

III. Results and Discussion

A. Network Parameter Data Collection Before Implementing Bandwidth Management Using the HTB Method

Network parameter data collection was conducted using Wireshark to measure the parameters of throughput, packet loss, delay, and jitter. A clearer illustration of this process can be seen in **Figure 5**.

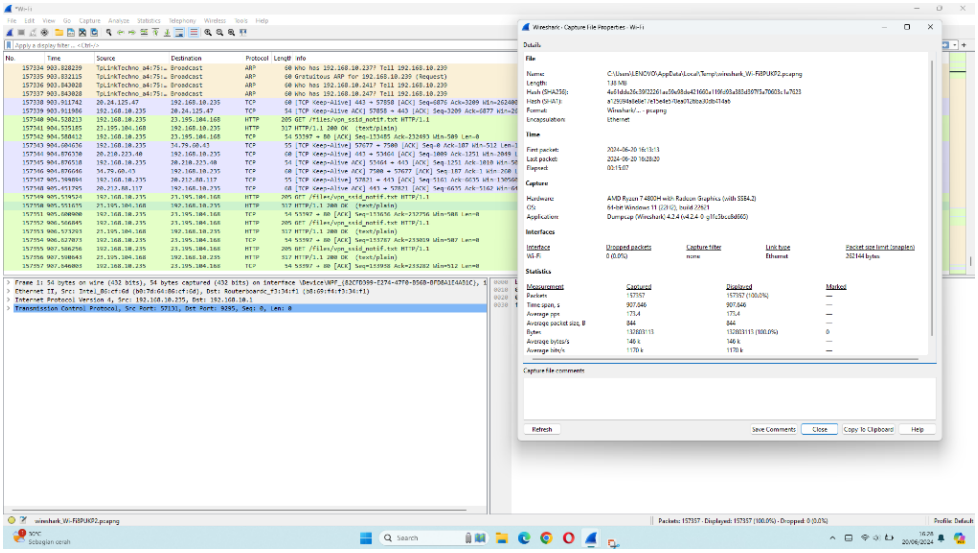

Figure 5. Network Parameter Data Collection

In **Table 1**, on June 20, Cluster 1 recorded a throughput value of 526 Kbps; on June 22, Cluster 2 recorded 480 Kbps; on June 23, Cluster 3 recorded 551 Kbps; and on June 24, Cluster 4 recorded 539 Kbps. The average throughput across all clusters was 524 Kbps, which falls under the moderate category.

Table 1. Pre-HTB Throughput Analysis

No	Research Time	Room	X- Throughput Value	Index	Category
1	20 June 2024	Cluster 1	526 Kbps	2	Fair
2	22 June 2024	Cluster 2	480 Kbps	2	Fair
3	23 June 2024	Cluster 3	551 Kbps	2	Fair
4	24 June 2024	Cluster 4	539 Kbps	2	Fair
	Average *Throughput*		524 Kbps	2	Fair

Table 2, on June 20 in Cluster 1, the packet loss value was 0.0%. On June 22 in Cluster 2, the packet loss was also 0.0%. On June 23 in Cluster 3, the packet loss remained 0.0%, and on June 24 in Cluster 4, the packet loss was 0.1%. The average packet loss was 0.00%, which falls into the excellent category.

Table 2. Packet Loss Before HTB

No	Research Time	Room	X- Packet Loss Value	Index	Category
1	20 June 2024	Cluster 1	0,0	4	Very Good
2	22 June 2024	Cluster 2	0,0	4	Very Good
3	23 June 2024	Cluster 3	0,0	4	Very Good
4	24 June 2024	Cluster 4	0,1	4	Very Good
	Average *Packet Loss*		0,0	4	Very Good

In **Table 3**, on June 20 in Cluster 1, the delay value was 95.381 ms. On June 22 in Cluster 2, the delay was 122.290 ms. On June 23 in Cluster 3, the delay was 114.152 ms, and on July 24 in Cluster 4, the delay was 160.509 ms. The average delay was 122.567 ms, which falls into the excellent category.

Table 3. Delay Analysis Before HTB

No	Research Time	Room	X- Delay Value	Index	Category
1	20 June 2024	Cluster 1	95,381 ms	4	Very Good
2	22 June 2024	Cluster 2	122,290 ms	4	Very Good
3	23 June 2024	Cluster 3	114,152 ms	4	Very Good
4	24 June 2024	Cluster 4	160,509 ms	4	Very Good

Average *Delay*	122,567 ms	4	Very Good

In **Table 4**, on June 20 in Cluster 1, the jitter value was 93.318 ms. On June 22 in Cluster 2, the jitter was 122.283 ms. On June 23 in Cluster 3, the jitter was 114.150 ms, and on June 24 in Cluster 4, the jitter was 160.506 ms. The average jitter was 122.564 ms, which falls into the good category.

Table 4. Jitter Analysis Before HTB

No	Research Time	Room	X- Jitter Value	Index	Category
1	20 June 2024	Cluster 1	93,318 ms	3	Good
2	22 June 2024	Cluster 2	122,283 ms	3	Good
3	23 June 2024	Cluster 3	114,150 ms	3	Good
4	24 June 2024	Cluster 4	160,506 ms	3	Fair
	Average *Jitter*		122,564 ms	3	Good

B. Network Parameter Data Collection After Implementing Bandwidth Management Using the HTB Method

In Figure 6, the use of the Winbox tool is shown as a utility for remotely accessing the MikroTik RB941 server. Here, configuration was carried out in the Queue List by creating a parent hierarchy named Klinik UIW PLN UIW, with the children being Cluster 1, Cluster 2, Cluster 3, and Cluster 4. This step enabled bandwidth allocation and management according to the existing network topology. After establishing the hierarchy with parents and children, bandwidth management was performed by assigning network speed limits to each child token configured in MikroTik via Winbox, using the Max Limit parameter.

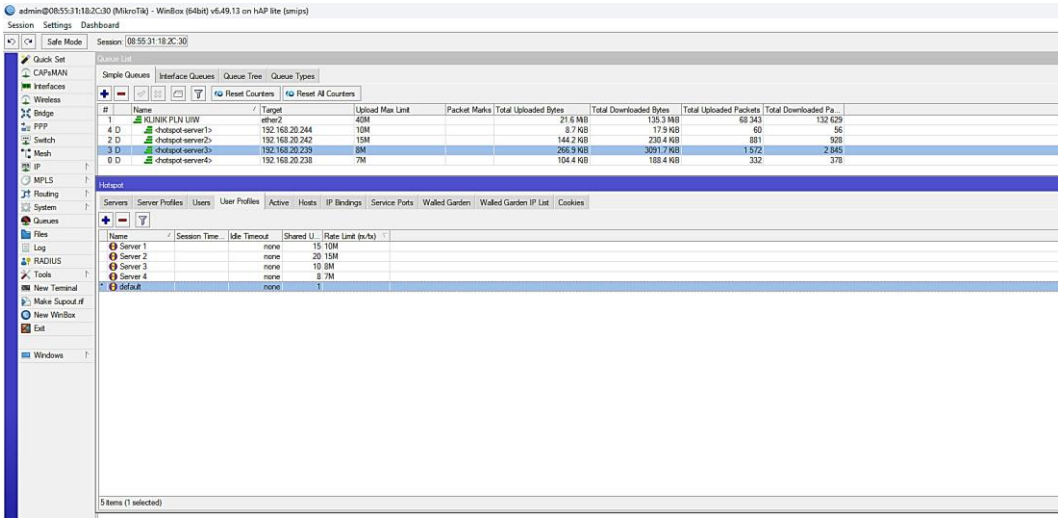

Figure 6. HTB Bandwidth Management

After applying bandwidth management using the Winbox tool, child configuration was performed for each cluster. Cluster 1 was assigned a Max Limit of 10 Mbps, ensuring that the maximum network speed would not exceed 10 Mbps during non-peak hours. Cluster 2 was assigned a Max Limit of 15 Mbps, keeping the network speed below 15 Mbps during low traffic. Cluster 3 was assigned a Max Limit of 8 Mbps, ensuring it does not exceed 8 Mbps. Finally, Cluster 4 was given a Max Limit of 7 Mbps, keeping its maximum network speed under 7 Mbps when idle. With this configuration, each cluster received a bandwidth allocation according to its needs, ensuring efficient and controlled network distribution.

In Table 5, on July 3 in Cluster 1, the recorded throughput was 1331 Kbps. On July 4 in Cluster 2, the throughput was 1748 Kbps. On July 5 in Cluster 3, the throughput reached 1826 Kbps, and on June 6 in Cluster 4, the throughput was 1649 Kbps. The average throughput was 1649 Kbps, which falls into the good category.

Table 6. Throughput Analysis After HTB

No	Research Time	Room	X- Throughput Value	Index	Category
1	20 June 2024	Cluster 1	1331 Kbps	3	Good
2	22 June 2024	Cluster 2	1748 Kbps	3	Good
3	23 June 2024	Cluster 3	1826 Kbps	3	Good
4	24 June 2024	Cluster 4	1694 Kbps	3	Good
	Average *Throughput*		1649 Kbps	3	Good

In **Table 6**, on July 3 in Cluster 1, the packet loss value was 0.0%. On July 4 in Cluster 2, the packet loss was also 0.0%. On July 5 in Cluster 3, the packet loss remained at 0.0%, and on July 6 in Cluster 4, the packet loss was also 0.0%. The average packet loss was 0.0%, which falls into the excellent category.

Table 6. Packet Loss Analysis After HTB

No	Research Time	Room	X- Packet Loss Value	Index	Category
1	20 June 2024	Cluster 1	0,0	4	Very Good
2	22 June 2024	Cluster 2	0,0	4	Very Good
3	23 June 2024	Cluster 3	0,0	4	Very Good
4	24 June 2024	Cluster 4	0,0	4	Very Good
	Average *Packet Loss*		0,0	0	Very Good

In **Table 7**, on July 3 in Cluster 1, the delay value was 51.560 ms. On July 4 in Cluster 2, the delay was 41.554 ms. On July 5 in Cluster 3, the delay was 31.857 ms, and on July 6 in Cluster 4, the delay was 35.724 ms. The average delay was 40.173 ms, which falls into the excellent category.

Table 7. Delay Analysis After HTB

No	Research Time	Room	X- Delay Value	Index	Category
1	20 June 2024	Cluster 1	51,560 ms	4	Very Good
2	22 June 2024	Cluster 2	41,554 ms	4	Very Good
3	23 June 2024	Cluster 3	31,857 ms	4	Very Good
4	24 June 2024	Cluster 4	35,724 ms	4	Very Good
	Average *Delay*		40,173 ms	4	Very Good

In Table 8, on July 3 in Cluster 1, the jitter value was 51.694 ms. On July 4 in Cluster 2, the jitter was 41.553 ms. On July 5 in Cluster 3, the jitter was 31.857 ms, and on July 6 in Cluster 4, the jitter was 36.724 ms. The average jitter was 40.452 ms, which falls into the excellent category.

Table 8. Jitter Analysis After HTB

No	Research Time	Room	X- Jitter Value	Index	Category
1	20 June 2024	Cluster 1	51,694 ms	4	Very Good
2	22 June 2024	Cluster 2	41,553 ms	4	Very Good
3	23 June 2024	Cluster 3	31,857 ms	4	Very Good
4	24 June 2024	Cluster 4	36,724 ms	4	Very Good
	Average *Jitter*		40,452 ms	4	Very Good

Based on the measurement results of the parameters before and after the implementation of the HTB method at Klinik Lisna YPK PLN Makassar 01 over a period of eight days (June 20, 22, 23, and 24, 2024 before implementation, and July 3, 4, 5, and 6, 2024 after implementation), the results were categorized according to the THIPON standard.

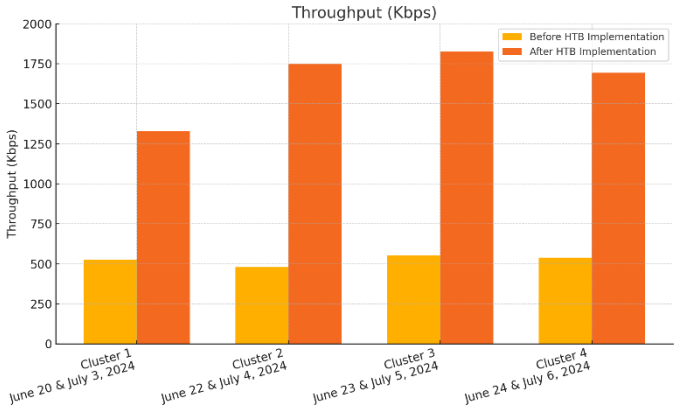

Figure 7. Throughput Before and After HTB

Based on the analysis in **Figure 7**, the average throughput before the implementation of HTB ranged from 480 Kbps to 551 Kbps, whereas after the implementation, it increased significantly to between 1331 Kbps and 1826 Kbps. The highest throughput before HTB was 551 Kbps (June 23, 2024), and the lowest was 480 Kbps (June 22, 2024). After HTB was applied, the highest throughput recorded was 1826 Kbps (July 5, 2024), and the lowest was 1331 Kbps (July 3, 2024). The average throughput increased from 524 Kbps before HTB to 1649 Kbps after HTB, indicating the need for increased bandwidth capacity and upgraded network devices.

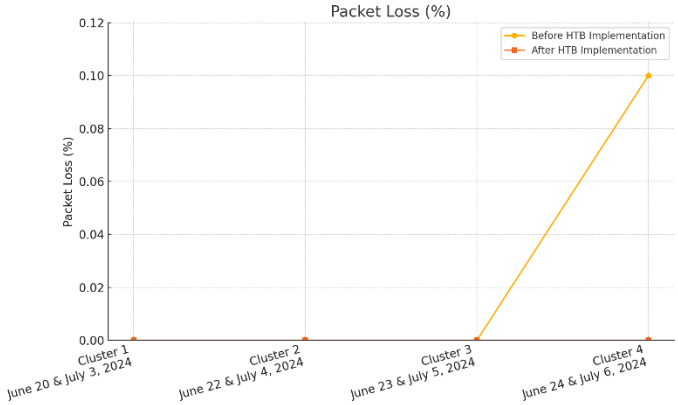

Figure 8. Packet Loss Before and After HTB

The analysis presented in **Figure 8** shows that the average packet loss before the implementation of HTB ranged from 0.0% to 0.1%, with the highest value recorded at 0.1% on June 24, 2024, and the lowest at 0.0%. After the implementation of HTB, packet loss remained consistently at 0.0% on all measurement days. The average packet loss improved from 0.01% before HTB to 0.0% after HTB, which aligns with the THIPON standard in the excellent category.

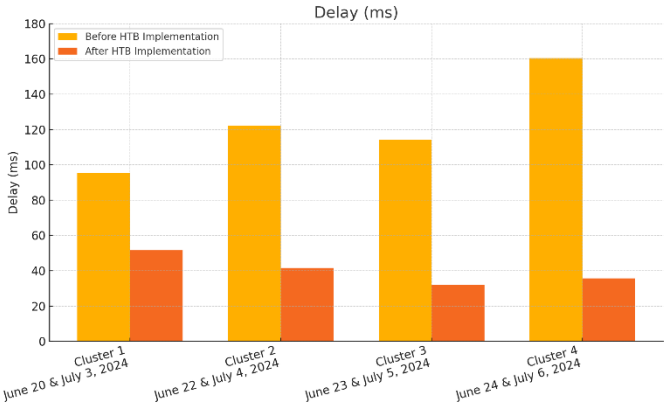

Figure 9. Delay Before and After HTB

From the analysis in **Figure 9**, the average delay before the implementation of HTB ranged between 93.318 ms and 160.509 ms, with the highest value recorded at 160.509 ms on June 24, 2024, and the lowest at 95.381 ms on June 20, 2024. After the implementation of HTB, the delay ranged from 31.857 ms to 51.560 ms, with the highest value being 51.560 ms on July 3, 2024, and the lowest being 31.857 ms on July 5, 2024. The average delay decreased from 122.567 ms before HTB to 40.173 ms after HTB, indicating an improvement in network quality in accordance with the THIPON standard.

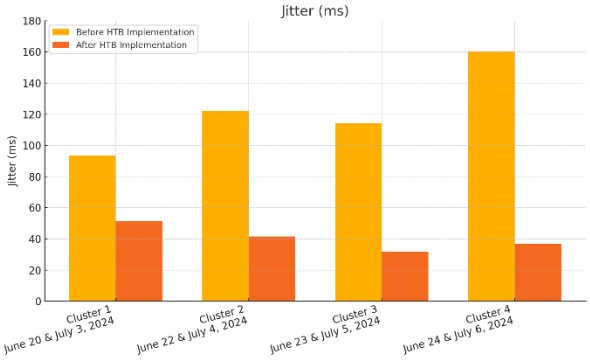

Figure 10. Jitter Before and After HTB

The jitter analysis in Figure 10 shows that the average jitter before implementing HTB ranged between 93.318 ms and 160.506 ms, with the highest value being 160.506 ms on June 24, 2024, and the lowest at 93.318 ms on June 20, 2024. After the HTB method was applied, jitter ranged from 31.857 ms to 51.694 ms, with the highest value at 51.694 ms on July 3, 2024, and the lowest at 31.857 ms on July 5, 2024. The average jitter decreased from 122.564 ms before HTB to 40.452 ms after HTB, showing a significant improvement in network performance in accordance with the THIPON standard.

IV. Conclusion

Based on the results of network performance testing before and after the implementation of bandwidth management using the Hierarchical Token Bucket (HTB) method at Klinik Lisna YPK PLN Makassar 01, it can be concluded that the application of HTB provided more accurate and improved results. The average delay after implementing HTB was 40.173 ms, compared to 122.567 ms before its implementation. The packet loss parameter also showed improvement, maintaining a value of 0.0% after HTB, compared to 0.1% previously. Throughput experienced a significant increase from 524 Kbps to 1649 Kbps after HTB was applied. Additionally, the jitter parameter showed improvement as well, decreasing from 122.564 ms to 40.452 ms. With the HTB method, bandwidth can be distributed and prioritized according to demand, allowing higher speeds for critical services, while areas that do not require high-speed connections are allocated lower bandwidth.

References

[1] F. Bistouni dan M. Jahanshahi, “Impact of raising switching stages on the reliability of interconnection networks,” *J. Inst. Electron. Comput.*, vol. 2, no. 1, hal. 93–120, 2020.

[2] “Jaringan masa depan: Gerakan melawan globalisasi perusahaan.”

[3] M. Sari, I. Sembiring, dan H. D. Purnomo, “Analysis of frontier’s internet network quality,” *J. Bumigora Inf. Technol.*, vol. 4, no. 2, hal. 205–216, 2022.

[4] I. P. Sari, “Analisis Penerapan Metode Antrian Hirarchical Token Bucket untuk Management Bandwidth Jaringan Internet,” vol. 2, no. 2, hal. 522–529, 2018, [Daring]. Tersedia pada: http://jurnal.iaii.or.id

[5] Fahmi, S. Yulita, dan S. Ramdan, “Analisis Quality of Service Menggunakan Delay, Packet Loss, Jitter dan Mean Opinon Score pada Voice Over IP,” *Pros. Semin. Nas. Ilmu Komput. dan Teknol. Inf.*, vol. 3, no. 2, hal. 93–96, 2018.

[6] M. I. Iskandar, R. Satra, dan L. Syafie, “Analisis Performansi Jaringan dengan Metode Per Connection Queue (PCQ) dan Hierarchical Token Bucket (HTB) di SMK Latanro Enrekang,” *Bul. Sist. Inf. dan*

Teknol. Islam, vol. 4, no. 1, hal. 15–24, 2023, doi: 10.33096/busiti.v4i1.1503.

[7] F. Khafif, "Peningkatan Pelayanan Internet Menggunakan Mikrotik Dan Software Winbox Di Ptipd Uin Walisongo Semarang," *Natl. Semin. Marit. Interdiscip. Stud.*, vol. 3, no. 1, hal. 264–267, 2021.

[8] A. Riady dan A. R. Mukthi, "Penerapan Manajemen Bandwidth Menggunakan Hierarchical Token Bucket Di PT. Bukit Energi Servis Terpadu," *J. Pengemb. Sist. Inf. dan Inform.*, vol. 2, no. 2, hal. 87–96, 2021, doi: 10.47747/jpsii.v2i2.549.

[9] Y. S. Putra, M. T. Indriastuti, dan F. S. Mukti, "Optimalisasi Nilai Throughput Jaringan Laboratorium Menggunakan Metode Hierarchical Token Bucket (Studi Kasus: Stmik Asia Malang)," *Netw. Eng. Res. Oper.*, vol. 5, no. 2, hal. 83–90, 2020, doi: 10.21107/nero.v5i2.161.

[10] S. Ahdan, O. Firmanto, dan S. Ramadona, "Rancang Bangun dan Analisis QoS (Quality of Service) Menggunakan Metode HTB (Hierarchical Token Bucket) pada RT/RW Net Perumahan Prasanti 2," *J. Teknoinfo*, vol. 12, no. 2, hal. 49, 2018, doi: 10.33365/jti.v12i2.89.

[11] Valia Yoga Pudya Ardhana dan M. D. Mulyodiputro, "Analisis Quality of Service (QoS) Jaringan Internet Universitas Menggunakan Metode Hierarchical Token Bucket (HTB)," *J. Informatics Manag. Inf. Technol.*, vol. 3, no. 2, hal. 70–76, 2023, doi: 10.47065/jimat.v3i2.257.

[12] D. Kurnia, "Analisis Qos Pada Pembagian Bandwidth Dengan Metode Layer 7 Protocol, Pcq, Htb Dan Hotspot Di Smk Swasta Al-Washliyah Pasar Senen," *CESS (Journal Comput. Eng. Syst. Sci.*, vol. 2, no. 2, hal. 102–111, 2017.

[13] R. Farizki dan others, "Analisis QOS Jaringan Internet Pada SMK Yadika 2," *Nusant. J. Multidiscip. Sci.*, vol. 1, no. 6, hal. 187–200, 2024.

[14] R. Rizky, Z. Hakim, S. Setiyowati, A. M. Yunita, dan others, "Development of the Multi-Channel Clustering Hierarchy Method for Increasing Performance in Wireless Sensor Network," *MATRIK J. Manajemen, Tek. Inform. dan Rekayasa Komput.*, vol. 23, no. 3, hal. 603–614, 2024.

[15] P. Gouveia *et al.*, "Kollaps: decentralized and dynamic topology emulation," in *Proceedings of the Fifteenth European Conference on Computer Systems*, 2020, hal. 1–16.

[16] F. I. Pamungkas, R. Satra, dan E. I. Alwi, "Buletin Sistem Informasi dan Teknologi Islam Perbandingan Manajemen Bandwidth Menggunakan Metode Per Connection Queue (PCQ) dan Hirarchical Token Bucket (HTB) INFORMASI ARTIKEL ABSTRAK," *Buletinndj*, vol. 2, no. 3, hal. 187–196, 2021.

[17] A. Firmansyah, A. Ijudin, N. Seha, R. N. Rahmawati, S. A. Peritami, dan others, "Analisis Kinerja Metode Simple Queue untuk Meningkatkan Kualitas Jaringan Manajemen Bandwith," *Digit. Transform. Technol.*, vol. 4, no. 1, hal. 244–251, 2024.