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Comparative Analysis of Quality of Service (QoS) on WLAN Network Bandwidth Management using HTB Method with PCQ

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ABSTRACT

This study explores bandwidth management on WLAN networks using Hierarchical Token Bucket (HTB) and Per Connection Queue (PCQ) methods to optimize Quality of Service (QoS). With the growing role of IT in both business and public sectors and increasing WLAN access, effective bandwidth management has become crucial to prevent certain users from monopolizing bandwidth for upload or download activities. The research involves data collection through observation and literature review, designing a network topology, implementing bandwidth management using HTB and PCQ, and analyzing performance with QoS parameters: throughput, delay, jitter, and packet loss. The results show that the HTB method achieves an average throughput of 97%, a delay of 98 ms, a jitter of 77 ms, and no packet loss, making it ideal for networks requiring priority-based bandwidth allocation for performance-sensitive applications. In contrast, the PCQ method yields an average throughput of 93.5%, a delay of 217 ms, a jitter of 55 ms, and no packet loss, which is better suited for evenly distributing bandwidth among users. Thus, HTB is recommended for priority-based networks, while PCQ supports fair bandwidth distribution across users.

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INTRODUCTION

The use of information technology (IT) has expanded beyond the business sector and is now widely adopted in the public sector as well. Internet access is increasingly facilitated by wireless networks. In the rapidly evolving digital era, wireless networks (WLANs) are a key infrastructure that supports connectivity for various applications and services, from data communication, to internet access. One of the main challenges in WLAN network management is ensuring adequate Quality of Service (QoS) service quality for users, especially in terms of throughput, delay, jitter, and packet loss.

Wireless network technology is employed to enhance the ease of wireless connectivity, including access to internet networks (Kusbandono and Syafitri (2019). Inefficient use of bandwidth capacity as a result of a resource-monopolized client can lead to a decrease in quality of service (QoS) for other users in the network. This phenomenon often occurs in WLAN network environments, where some clients can consume most of the available bandwidth, leaving the rest of the users with slow or intermittent connections.

Effective bandwidth management is one method of ensuring network service quality, commonly referred to as Quality of Service (QoS) (Libratama and Irmayani, 2018). The key parameters to consider when determining Quality of Service (QoS) are throughput, delay, jitter, and packet loss (Sukri and Jumiati, 2017). Bandwidth management methods are the main focus to optimize QoS in WLAN networks. The two common approaches used are Hierarchical Token Bucket (HTB) and Per Connection Queue (PCQ). HTB organizes bandwidth allocation in a hierarchical manner, while PCQ gives priority to each connection.

However, there is no clear consensus on the relative effectiveness of the two methods in optimizing QoS on WLAN networks. Therefore, this study aims to conduct a comparative analysis between HTB and PCQ in the context of bandwidth management in WLAN networks, focusing on throughput, delay, jitter, and packet loss parameters.

THEORETICAL REVIEW

Bandwidth Management

Bandwidth management involves measuring and controlling the flow of data within a computer network to prevent issues such as network congestion and performance degradation (Septiawan, 2013). Effective bandwidth management should be capable of creating and maintaining rules to ensure the availability of connections, such as internet access.

The Hierarchical Tocken Bucket (HTB) method was developed by Martin Devera, this method is used to restrict access to certain ports/IPs without interfering with other users' bandwidth traffic (Sidqi, 2021). The HTB bandwidth management method is a queuing technique that can provide traffic restrictions at each level or classification. With this HTB management, unused bandwidth can be used by lower classifications (Pratama, Ependi and Suroyo, 2019).

The Per Connection Queue (PCQ) method is a program to manage the Quality of Service (QoS) traffic network (Towidjojo, 2013). Per Connection

Queuing (PCQ) is used as a queue method on networks with a large number of clients, or networks with an unpredictable number of clients (Sulistiyawati & Supriyanto, 2021). PCQ works by creating sub-streams based on pcq-classifier parameters which can be in the form of sender IP address (src-address), destination IP address (dst-address) (Hidayat, 2014).

Wireless Local Area Network (WLAN)

A Wireless Local Area Network (WLAN) is a computer network that uses radio and infrared frequencies for data transmission. Often referred to simply as a wireless network, WLAN operates using radio waves (Utomo, 2015).

Quality of Service (QoS)

Quality of Service (QoS) is a method for assessing network performance and defining the characteristics and attributes of a service. It measures a specific set of performance metrics that are associated with the quality of the service delivered (Febriyanti et al., 2017). Quality of Service (QoS) pertains to a network's ability to provide improved services for particular types of network traffic using various technologies. It facilitates the definition of network service attributes in both qualitative and quantitative terms

Table 1. Quality of Service (QoS) percentage and value

Value;	Percentage (%)	Index
3,8 - 4	95 - 100	Very satisfying
3 - 3,79	75 - 94,75	Satisfying
2 - 2,99	50 - 74,75	Less than satisfactory
1 - 1,99	25 - 49,75	Bad

(Tiphon, 1999)

The purpose of Quality of Service (QoS) is to address diverse service requirements while utilizing the same infrastructure. Key elements of network performance within the scope of QoS often include availability (uptime), bandwidth (throughput), latency (delay), and error rates. Parameters commonly used for assessing Quality of Service (QoS) include throughput, delay (latency), jitter (variation in packet arrival), and packet loss (Pratama et al., 2015).

Throughput refers to the effective data transfer rate, measured in bits per second (bps). It is calculated as the total number of successful packet arrivals at a destination during a specific time interval, divided by the duration of that interval.

Tabel 2. Parameter Throughput

Throughput Category	Throughput	Index
Very Good	100 %	4
Good	75 %	3
Keep	50 %	2

Throughput Category	Throughput	Index
Bad	< 25 %	1

(Tiphon, 1999)

$$Throughput\ calculation\ equation:$$

$$Throughput = \frac{Paket\ data\ diterima}{Lama\ pengamatan}$$

Delay (Latency) is the total time it takes for a packet to travel from the sender to the receiver across the network. Factors influencing delay include distance, physical media, network congestion, and prolonged processing times.

Table 3. Delay (Latency) Parameter

Latency Category	Large Delay	Index
Very Good	< 150 ms	4
Good	150 s/d 300 ms	3
Keep	300 s/d 450 ms	2
Bad	> 450 ms	1

(Tiphon, 1999)

$$Latency\ calculation\ equation:$$

$$Delay\ rata - rata = \frac{Total\ delay}{Total\ pcket\ yang\ diterima}$$

Jitter, or variation in packet arrival times, refers to the fluctuations in end-to-end delay. High levels of jitter are unacceptable in UDP-based real-time applications, as they can distort the signal. In such cases, increasing the buffer in the queue can help mitigate the effects of jitter.

Table 4. Jitter Parameters

Categories Degradation	Peak Jitter	Index
Very Good	0 ms	4
Good	0 s/d 75 ms	3
Keep	75 s/d 125 ms	2
Bad	125 s/d 225 ms	1

(Tiphon, 1999)

$$Jitter\ calculation\ equation:$$

$$Jitter = \frac{Total\ variansi\ delay}{Total\ pcket\ yang\ diterima}$$

Packet loss is a parameter that indicates the total number of packets that are lost during transmission, which can occur due to collisions and network congestion.

Tabel 5. Parameter Packet Loss

Category Degradation	Packet Loss	Indeks
Very Good	0 %	4
Good	3 %	3
Keep	15 %	2
Bad	25 %	1

Tiphon, 1999)

$$Packet\ Loss\ calculation\ equation: Packet\ Loss = \left(\frac{Data\ yang\ dikirim - paket\ data\ yang\ diterima}{Paket\ data\ yang\ dikirim}\right) \times 100\%$$

METHODOLOGY

This research employs experimental methods alongside literature studies to investigate the processes associated with each parameter and variable. The data collection methods utilized include observation and literature review. Observation involves gathering data through direct examination of the research object to obtain an accurate depiction of bandwidth management implementation using HTB and PCQ on WLAN. Concurrently, the literature review entails collecting data and information that serve as references related to WLAN implementation, bandwidth management with HTB and PCQ, and Quality of Service.

The method used to assess the quality of service and performance on the Wireless LAN (WLAN) network is Quality of Service (QoS), evaluated through parameters such as throughput, delay, jitter, and packet loss. This study compares bandwidth management techniques utilizing Hierarchical Token Bucket (HTB) and Per Connection Queue (PCQ).

The bandwidth utilized is 10 Mbps for both upload and download, with 10 clients (laptops/notebooks) connected to the access point (WLAN). The tools and materials used in this research include hardware components such as a router (Mikrotik RB1100x4), a WLAN device (Linksys LAPN300) operating on a single band (2.4 GHz), and a computer (laptop/notebook) designated for collecting data on bandwidth management implementation results and conducting QoS analysis. The software used is the wireshark application (www.wireshark.org) and speedtest (speed.cloudflare.com).

RESULTS

WLAN Network Topology

At this stage, the focus is on designing and testing the Wireless LAN (WLAN) network. The setup includes an internet connection from an ISP (Internet Service Provider) via an ONT (Optical Network Terminal) with a speed capacity of 10 Mbps. The router used is a Mikrotik RB1100x4, and the Access Point is a Linksys LAPN300 operating on a single band (2.4 GHz). For connection testing, a laptop or notebook is utilized to connect to the Access Point. The results of the design of the wireless LAN network (WLAN) topology that was tested are shown in Figure 1

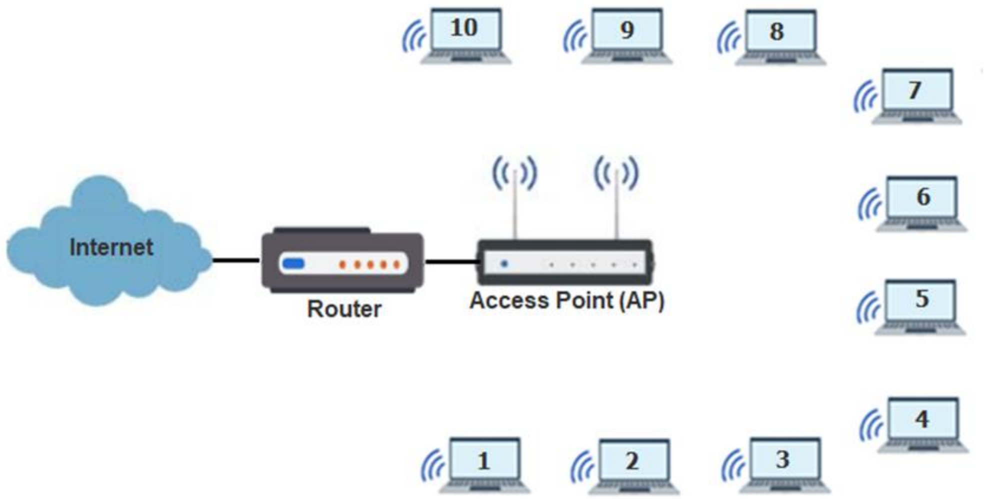

Figure 1. WLAN network topology design

Bandwidth Management

At the implementation stage of Hierarchical Token Bucket (HTB) bandwidth management, a simple queue was designed on the Mikrotik router. The target used is 10 clients (Laptops) with IP Network 192.168.1.1/28.

Figure 2. is the result of configuring the implementation of Hierarchical Token Bucket (HTB) bandwidth management using a simple queue on a Mikrotik router. The parameters used are that each client (Laptop) will get a bandwidth limit in the form of an upload and download limit of 1 Mbps, or will get a maximum bandwidth capacity of 10 Mbps.

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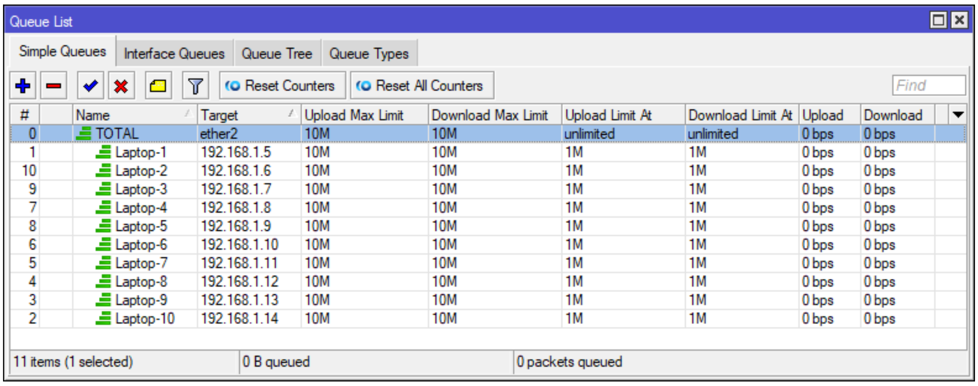
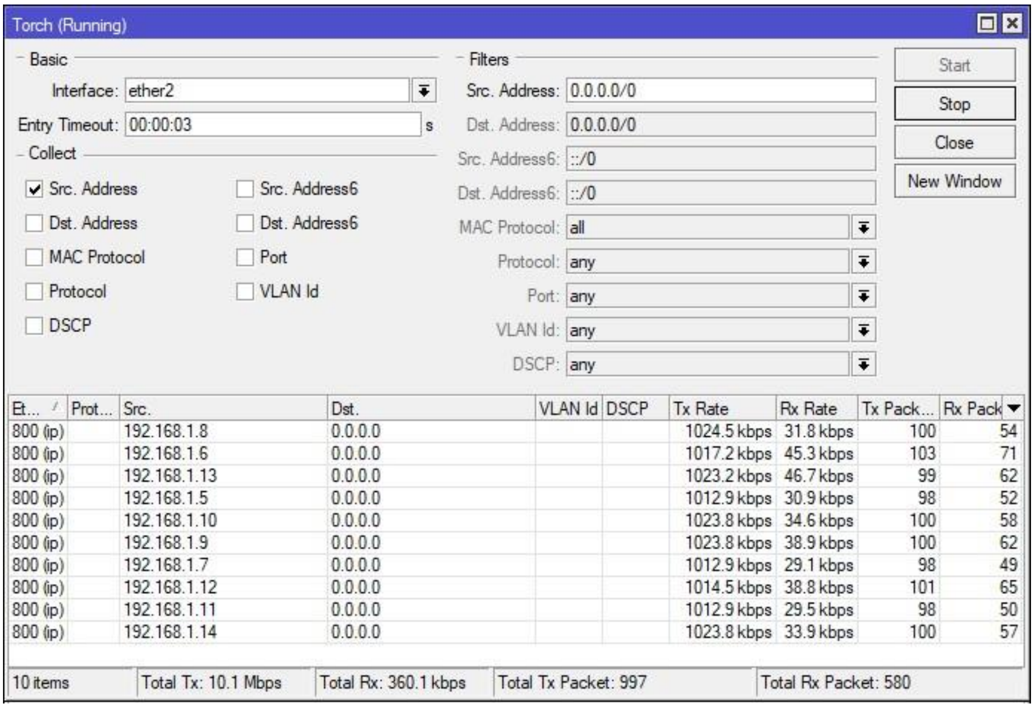


#	Name	Target	Upload Max Limit	Download Max Limit	Upload Limit At	Download Limit At	Upload	Download
0	TOTAL	ether2	10M	10M	unlimited	unlimited	0 bps	0 bps
1	Laptop-1	192.168.1.5	10M	10M	1M	1M	0 bps	0 bps
10	Laptop-2	192.168.1.6	10M	10M	1M	1M	0 bps	0 bps
9	Laptop-3	192.168.1.7	10M	10M	1M	1M	0 bps	0 bps
7	Laptop-4	192.168.1.8	10M	10M	1M	1M	0 bps	0 bps
8	Laptop-5	192.168.1.9	10M	10M	1M	1M	0 bps	0 bps
6	Laptop-6	192.168.1.10	10M	10M	1M	1M	0 bps	0 bps
5	Laptop-7	192.168.1.11	10M	10M	1M	1M	0 bps	0 bps
4	Laptop-8	192.168.1.12	10M	10M	1M	1M	0 bps	0 bps
3	Laptop-9	192.168.1.13	10M	10M	1M	1M	0 bps	0 bps
2	Laptop-10	192.168.1.14	10M	10M	1M	1M	0 bps	0 bps

11 items (1 selected) | 0 B queued | 0 packets queued

Figure 2. Bandwidth management using the HTB method

The results of the HTB method bandwidth management test on each device/client (Laptop) using a torch on Mikrotik, display the traffic capacity information obtained by each device (Laptop).



Et...	Prot...	Src.	Dst.	VLAN Id	DSCP	Tx Rate	Rx Rate	Tx Pack...	Rx Pack
800 (ip)		192.168.1.8	0.0.0.0			1024.5 kbps	31.8 kbps	100	54
800 (ip)		192.168.1.6	0.0.0.0			1017.2 kbps	45.3 kbps	103	71
800 (ip)		192.168.1.13	0.0.0.0			1023.2 kbps	46.7 kbps	99	62
800 (ip)		192.168.1.5	0.0.0.0			1012.9 kbps	30.9 kbps	98	52
800 (ip)		192.168.1.10	0.0.0.0			1023.8 kbps	34.6 kbps	100	58
800 (ip)		192.168.1.9	0.0.0.0			1023.8 kbps	38.9 kbps	100	62
800 (ip)		192.168.1.7	0.0.0.0			1012.9 kbps	29.1 kbps	98	49
800 (ip)		192.168.1.12	0.0.0.0			1014.5 kbps	38.8 kbps	101	65
800 (ip)		192.168.1.11	0.0.0.0			1012.9 kbps	29.5 kbps	98	50
800 (ip)		192.168.1.14	0.0.0.0			1023.8 kbps	33.9 kbps	100	57

10 items | Total Tx: 10.1 Mbps | Total Rx: 360.1 kbps | Total Tx Packet: 997 | Total Rx Packet: 580

Figure 3. HTB method test results using Torch

The results of the implementation of PCQ bandwidth management using a simple queue with a maximum bandwidth capacity will get 10 Mbps.

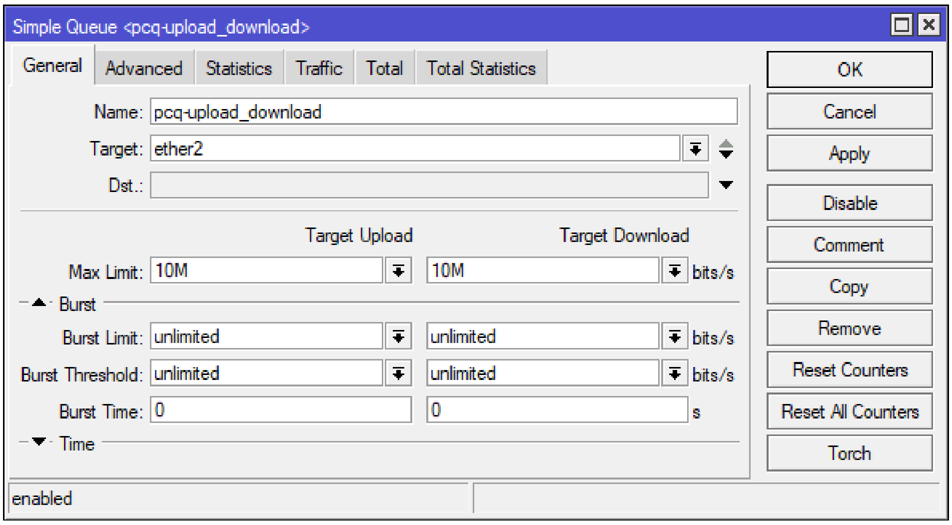


Figure 4. PCQ bandwidth management at Max Limit

Results of bandwidth management torch testing using PCQ Figure 5. shows that each device (Laptop) gets a bandwidth capacity of ± 1 Mbps with the condition that all devices use traffic

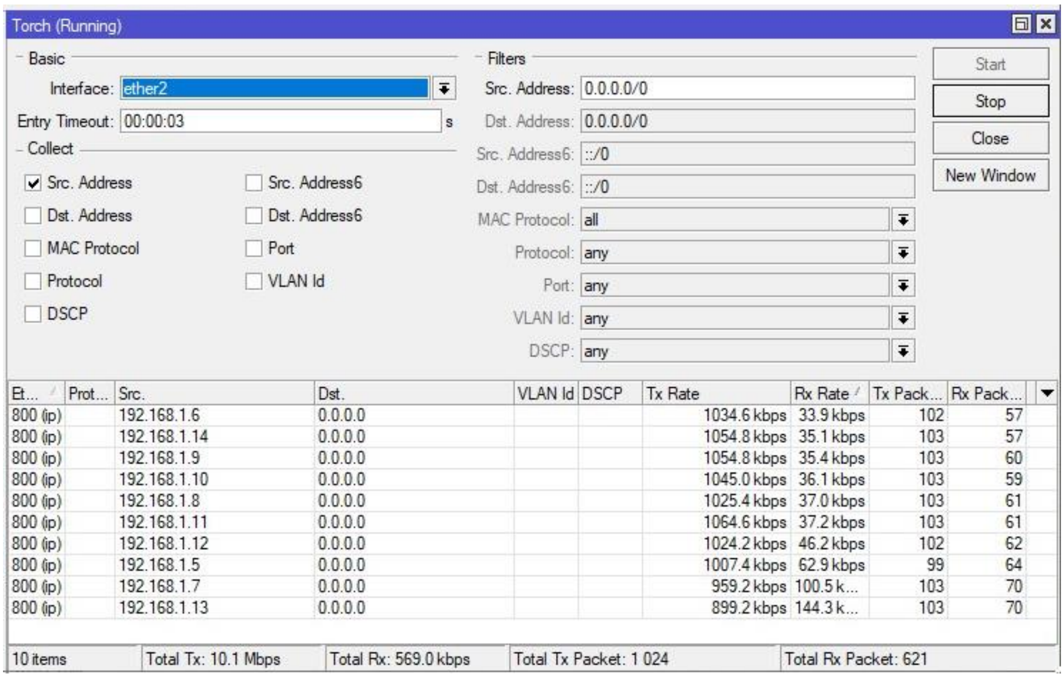


Figure 5. PCQ method test results using torch

Quality of Service (QoS) Testing

Based on the results of the bandwidth management test using the Hierarchical Token Bucket (HTB) method, as shown in Table 6, the Quality of Service (QoS) evaluation for uploads yielded the following results: the throughput parameter was categorized as 'Good' with an average throughput value of 98%, while the delay parameter fell into the 'Very Good' category with an average delay of 121 ms. The jitter parameter was also rated as 'Good' with an average jitter value of 60 ms, and the packet loss parameter was classified as

'Very Good' with an average packet loss rate of 0.0%. For downloads, the throughput parameter was again rated as 'Good' with an average throughput value of 96%, the delay parameter as 'Very Good' with an average delay of 75 ms, the jitter parameter as 'Good' with an average jitter of 95 ms, and the packet loss parameter maintained a 'Very Good' classification with an average packet loss rate of 0.0%.

Table 6. HTB testing average

Parameters	Upload			Download		
	Average	**Index**	**Information**	**Average**	**Index**	**Information**
Throughput	98%	3	Good	96%	3	Good
Delay	121 ms	4	Very Good	75 ms	4	Very Good
Jitter	60 ms	3	Good	95 ms	3	Good
Packet loss	0.0%	4	Very Good	0.0%	4	Very Good

Based on the results of bandwidth management testing using Per Connection Queue (PCQ), as presented in Table 7, the Quality of Service (QoS) assessment for uploads yielded the following results: the throughput parameter was classified in the 'Good' degradation category, with an average throughput value of 93%. The delay parameter also fell into the 'Good' category, showing an average delay of 277 ms. The jitter parameter was rated as 'Medium' with an average jitter value of 74 ms, while the packet loss parameter was categorized as 'Very Good' with an average packet loss rate of 0.0%. For downloads, the throughput parameter was rated 'Good' with an average throughput value of 94%, the delay parameter was classified as 'Good' with an average delay of 158 ms, and the jitter parameter was also rated as 'Good' with an average jitter of 37 ms. The packet loss parameter maintained a 'Very Good' classification, with an average packet loss rate of 0.0%.

Table 7. PCQ test average

Parameter	Upload			Download		
	Average	**Index**	**Information**	**Average**	**Index**	**Information**
Throughput	93%	3	Good	94%	3	Good
Delay	277 ms	3	Good	158 ms	3	Good
Jitter	74 ms	3	Good	37 ms	3	Good
Packet loss	0.0%	4	Very Good	0.0%	4	Very Good

Based on the results of the Quality of Service (QoS) test with percentages and values on bandwidth management using HTB and PCQ with QoS parameters shown in Table 4.8 showing the percentage and value of Quality of Service (QoS) bandwidth management using HTB with an average value of 3.5 uploads and 3.3 downloads with a QoS index of "Satisfactory". Meanwhile, bandwidth management uses PCQ with an average value of 3.25 uploads and 3.23 downloads with a QoS index of "Satisfactory".

Table 4.8. Quality of Service (QoS) percentage and value

Parameter	HTB		PCQ	
	Upload Index	**Download Index**	**Upload Index**	**Download Index**
Throughput	3	3	3	3
Delay	4	4	3	3
Jitter	3	3	3	3
Packet loss	4	4	4	4
Average Score	3,5	3,5	3,25	3,25
QoS Index	Satisfying	Satisfying	Satisfying	Satisfying

Quality of Service (QoS) Analysis

In the performance analysis of the HTB bandwidth management method with PCQ, several key parameters of throughput, packet loss, latency, and jitter can be used as a reference to understand the advantages and disadvantages of each method.

Throughput

HTB shows a significant advantage in terms of throughput which reflects its ability to allocate bandwidth in a more structured manner, especially on networks that require specific prioritization. This method uses a hierarchical approach where bandwidth is allocated tiered according to the needs of the application or traffic class, allowing for more efficient handling of applications with high bandwidth requirements. In contrast, the PCQ method, which divides bandwidth based on the number of active connections and not based on application priority. So that the throughput shows many connections at once with a more even distribution. In scenarios with multiple users who have similar bandwidth needs, this method is quite effective.

Latency

HTB has a lower average latency of 20 ms, compared to PCQ which reaches 35 ms. This shows that HTB is superior in responding, especially for critical applications that require short response times. While the higher latency on PCQ indicates that a more even distribution of bandwidth can lead to significant latency.

Jitter

In terms of jitter, PCQ showed better performance with an average of 5 ms compared to 10 ms on HTB. Low jitter on PCQ signifies better stability of packet delivery times, especially for applications such as VoIP and video streaming.

Packet Loss

In terms of packet loss, PCQ is superior with an average of 0%, lower than HTB which reaches 0.3%. PCQ is more effective in maintaining the stability of real-time application data transmission such as VoIP. On the other hand, although HTB is able to produce higher throughput, this method tends to experience increased packet loss in congested network conditions due to the priority management system on bandwidth management.

DISCUSSION

PCQ throughput parameters divide evenly among multiple connections, ensuring each user gets a balanced portion of bandwidth. In contrast, HTB excels at maintaining stable throughput because it is able to allocate bandwidth based on traffic priority levels. The PCQ delay parameter increases as the number of active connections increases, due to the uniform distribution of bandwidth. Meanwhile, HTB is more efficient in reducing delays thanks to structured bandwidth settings, allowing for more responsive handling of priority traffic. PCQ tends to produce higher jitter when the network load increases, especially if many connections are active. Meanwhile, HTB is able to keep jitter low and consistent, thanks to bandwidth management that is more focused on data flow stability.

CONCLUSIONS AND RECOMMENDATIONS

PCQ is ideal for environments with many connections that require a fair distribution of bandwidth among users. In contrast, HTB is ideal for networks that require priority-based bandwidth control, ensuring optimal performance on applications or services that are sensitive to network performance.

FURTHER STUDY

he researchers recognize that this article is not perfect and apologize for any errors it may contain. We hope that this research will offer valuable insights and benefits to all who reference it.

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REFERENCES

A. W. Azinar dan R. S. Adi. 2017., "Analisis QoS (Quality of Service) pada Warnet dengan Metode HTB (Hierarchical Token Bucket)" J. Ilm. Nero, vol. 3, no. 1, pp. 45–52, 2017.

Febriyanti, dkk. 2107. "Perbandingan Manajemen Bandwidth Menggunakan Metode FIFO (First-In First-Out) dan PCQ (Per Connection Queue) pada Router Mikrotik". Jurnal JARKOM Vol. 5 No. 2 Juni 2017.

Hidayat, R. (2014). Sistem Informasi Ekspedisi Barang Dengan Metode E-CRM Untuk Meningkatkan Pelayanan Pelanggan. Sisfotek Global.

Kusbandono, Lestariningsih, Ismar. "2023. Analysis of First InFirst Out (FIFO) Bandwidth Packet Queuing Technique with Random Early Detection (RED) on WLAN (Wireless LAN)". East Asian Journal of Multidisciplinary Research (EAJMR). Vol.2, No.8, 2023: 3335-3344.

Kusbandono, Syafitri. 2019. "Penerapan Quality Of Service (QoS) dengan Metode PCQ untuk Manajemen Bandwidth Internet pada WLAN Politeknik Negeri Madiun". Jurnal Research : Journal of Computer, information system, & technology management. Vol. 2, No. 1. April 2019, Pages 7-12.

Libratama, Irmayani. 2018. "Optimalisasi Performansi Sirkit Dedicated Line Melalui Pengaturan Bandwidth User dengan Metode Traffic Shaping". Jurnal Sinusoida Vol. XX No. 2, April 2018.

Mirsanto, dkk. 2015. Implementasi dan Analisa Per Connection Queue (PCQ) Sebagai Kontrol Penggunaan Internet pada Laboratorium Komputer. Jurnal Media Infotama Vol. 11 No. 2, September 2015.

Mujahidin, Tafaul. 2011. "OS Mikrotik Sebagai Manajemen Bandwidth dengan Menerapkan Metode Per Connection Queue". Naskah Publikasi. Yogyakarta; Amikom.

Nur, A. (2021). Pasien Berbasis Mobile (Studi Kasus : Klinik Bersalin Nurhasanah). 2(2), 1–6.

Nurcahyo, Firgia, Himamunanto. 2021. "Perbandingan Algoritma RED, SFQ, dan AQM pada Jaringan Enterprise dengan Vmware Esxi dan Router OS". Jurnal Informasi Interaktif Vol. 6 No. 3, Pages 101-110.

Pello dan Efendi. 2021. "Analisis Quality of Service menggunakan Metode Hierarchical Token Bucket". JIKO (Jurnal Informatika dan Komputer); Vol. 4, No. 3, Desember 2021, hlm. 193-198.

Pratama, Ependi, dan Suroyo. 2019. "Optimasi Kinerja Jaringan Nirkabel menggunakan Hierarchical Token Bucket". Journal of Information

Systems and Informatics; Vol. 1, No. 1, March 2019 e-ISSN: 2656-4882 p-ISSN: 2656-5935.

Pratama, Irwansyah, Yulianti. 2015. "Perbandingan Metode PCQ, SFQ, RED dan FIFO pada Mikrotik Sebagai Upaya Optimalisasi Layanan Jaringan pada Fakultas Teknik Universitas Tanjungpura". Jurnal Justin. Vol 3, No 3. 2015.

Septiawan, Didit Aji. 2013. "Membangun Prioritasisasi Lalu Lintas Data (Internet) Menggunakan HTB Queueing Disciplines Pada Jaringan Lokal SMK N 1 Nanggulan". Naskah Publikasi; Amikom Yogyakarta.

Sidqi. 2021. "Quality of Service Wireless LAN 802.11n untuk Optimalisasi Manajemen Bandwidth menggunakan metode Hierarchical Tocken Bucket". Journal of Informatics and Communications Technology (JICT); VOL. 3, NO. 2, PP.040-050, DES 2021.

Sugandi, Juardi, dan Ridha. 2023. "Implementasi Metode Hierarchical Token Bucket (HTB) dalam Manajemen Bandwith Jaringan Internet". JATI (Jurnal Mahasiswa Teknik Informatika); Vol. 7 No. 4, Agustus 2023.

Sukadarmika, G. dkk (2010). "Analisis Coverage WLAN (Wireless Local Area Network) 802.11a Menggunakan Opnet Modeler". Teknologi Elektro Vol. 9 N 143 o.2 Juli - Desember 2010.

Sukri, Jumiati. 2017. "Analisa Bandwidth Menggunakan Metode Antrian Per Connection Queue". Jurnal RABIT; Vol. 2 No. 2, Juli 2017.

Sulistiyawati, A., & Supriyanto, E. (2021). Implementasi Algoritma K-means Clustring dalam Penetuan Siswa Kelas Unggulan. Jurnal Tekno Kompak, 15(2), 25. https://doi.org/10.33365/jtk.v15i2.1162.

T. Akbar, 2018. "Implementasi Manajemen Bandwidth Router Mikrotik Menggunakan Metode Hierarchical Token Bucket (HTB) Di Smk Bina Mandiri," Fak. Tek. Univ. Negeri Jakarta, no. Pengembangan Alat peraga Matematika Untuk Meningkatkan Minat dan Motivasi Belajar siswa Sekolah Dasar, pp. 33–34, 2018.

T.O. Sidqi, I. Fitri, dan N.D. Nathashia. 2021. "Implementasi Manajemen Bandwith Menggunakan Metode HTB (Hierarchical Token Bucket) Pada Jaringan Mikrotik". JIPI (Jurnal Ilmiah Penelitian dan Pembelajaran Informatika). Volume 06, Nomor 01, Juni 2021 : 132 - 138.

TIPHON., 1999. Telecommunications and Internet Protocol Harmonization Over Network (TIPHON) General aspects of Quality of Service (QoS). Jurnal, 1.

Towidjojo, R., 2016. Mikrotik Kungfu : kitab 3. Jasakom.

Utomo, Pryo (2015), "Intalasi Jaringan WLAN menggunakan access point LYNKSYS WRT54G di SMK taman siswa medan" Pendidikan Teknik Elektro Fakultas Teknik Universitas Negeri Medan.