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Improving Internet Network Performance through Bandwidth Management

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***Abstract*— The bandwidth available on the network must be managed. In this paper, hierarchical tocken bucket (HTB) and class based queuing (CBQ) methods are used to manage bandwidth. As well as measuring customer satisfaction in the form of a customer satisfaction index (CSI). Quality of service (QoS) performance that is reviewed is throughput, delay, packet loss, and jitter. Based on the results of measurement analysis for the four QoS performance, internet network performance using HTB method shows better performance than CBQ performance. And the level of customer satisfaction with internet services using the HTB method is higher than the CBQ method.**

***Keywords*— bandwidth, quality of service, hierarchical tocken bucket, class based queueing, customer satisfaction index.**

I. INTRODUCTION

Information and communication technology from time to time continues to develop. In line with this, the need for information quickly and accurately has become a new demand in the fields of government, education, and business. One of the most efficient electronic media in disseminating and receiving information is called the internet [1].

The education sector requires very high internet access. This is due to a large number of users of internet services and administrative information systems that manually switch to using online services. Thus, there will be more and more applications served by the network. For all these services to run well, bandwidth availability must be considered for each user. The inability to allocate the amount of bandwidth appropriately can result in the data processing mechanism being hampered and affecting overall network performance [2]. The problem that can occur are communication services are not optimal, failure of the data transmission process, upload, and download processes take longer, there is a pile of data packets (congestion), hardware latency, and losses [3].

This condition causes users to be unable to use the internet smoothly and tends to result in delayed activity and blocked information.

To overcome this, a method is needed to manage the bandwidth used. The stochastic fairness queuing (SFC) method is a probabilistic variant algorithm of the justice queue. This method does not require precise mapping so it is suitable for implementation in high-speed software or firmware [4].

Next, we present the token bucket filter (TBF) method for the Luster file system. TBF imposes a limit on remote procedure call (RPC) rates based on quality of service (QoS) rules. QoS rules are enforced on the Luster object storage server, where each request is assigned to an automatically generated QoS class. The proposed QoS implementation for Luster allows a variety of features for each class including support for high priority and real-time requests even under heavy loads and utilization of spare bandwidth with less critical tasks under light loads. [5].

The class based queuing (CBQ) method was developed by the Network Research Group at Lawrence Berkeley National Laboratory. The application of traffic and bandwidth management using the CBQ method can assure service quality, can give priority to critical applications on the network such as server applications, and maximize bandwidth usage [6]. The router sets up a queue for each class at a priority level and assigns the available bandwidth to that class. In the mechanism, the upper limit of the available bandwidth for each class is changed dynamically due to the large queue space in each class. The CBQ method provides more flexible bandwidth control and increases the effectiveness of the entire network [7]. The performance of the CBQ method is in the form of latency, guaranteed bandwidth, and delay. The results obtained from the CBQ method are more suitable for providing guaranteed bandwidth to the aggregate data stream [8].

The hierarchical tocken bucket method (HTB) was developed by Martin Devera. The HTB is meant as a more understandable and intuitive replacement for the CBQ.

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The HTB is a newer technology than the CBQ. The HTB method can properly limit the bandwidth of all existing clients and the imanbw (bandwidth management information) program was developed to assist administrators in bandwidth management in the network [9]. The application of this method is carried out on IEEE 802.11 wireless local area networks. The results obtained on the IEEE 802.11b testbed are that the HTB method can be applied to the network. The HTB concept can be extended to wireless scenarios and can be implemented in the IEEE 802.11e standard [10]. The HTB method is applied to the case study of the Muhammadiyah University of Palembang with the measured performance is throughput, delay, and packet loss. The result is that the network quality is more optimal, this is because the bandwidth will be divided according to the rules applied to bandwidth management and clients are not fighting over bandwidth [11].

Several methods have been used in the network but this study analyzing the internet network (a case study of Dhyana Pura University) with the HTB and CBQ methods. As well as measuring customer satisfaction in the form of CSI. The purpose of this research is the performance of QoS in the internet network following TIPHON standards and to find out better methods of providing internet network services.

II. Network Performance

A. Quality of Service

Quality of Service is used to measure the performance level of a TCP / IP network connection or computer network [12]. Quality of Service defines the reliability of a network in providing good service for traffic services that pass through it. The parameters of QoS include throughput, delay, packet loss, and jitter.

i) Throughput

Throughput is measured in bps (bits per second), which is the speed (rate) of effective data transmission [13]. The throughput can be calculated using the following equation:

$$Throughput = \frac{data\ packet\ received}{observation\ time} \quad (1)$$

The throughput category can be seen in Table 1 [10].

TABLE I
Throughput Category

Category	Thoughput (bps)	Index
Excellent	100	4
Good	75	3
Medium	50	2
Bad	<25	1

ii) Delay

Delay is measured in milliseconds (ms), which is the time it takes for data to arrive at its destination. Delay is affected by distance, hardware, or congestion during transmission [13]. To calculate delay use the following equation:

$$Delay\ average = \frac{Total\ delay}{Total\ packet\ received} \quad (2)$$

The delay category can be seen in Table 2 [13].

TABLE II
Delay Category

Category	Delay (ms)	Index
Excellent	<150	4
Good	150 s/d 300	3
Medium	300 s/d 450	2
Bad	>450	1

iii) Packet Loss

Packet loss is defined as the number of packets that do not arrive (fail) when the packet is sent. Large packet loss value is defined as the network is busy (overload) [13]. Packet loss can be calculated using equation (3)

$$Packet\ loss = \frac{(data\ packets\ are\ sent - data\ packet\ received}{data\ packets\ are\ sent} x100 \quad (3)$$

The packet loss category can be seen in Table 3 below [13]:

TABLE III
Packet Loss Category

Category	Packet Loss (%)	Index
Excellent	0	4
Good	3	3
Medium	15	2
Bad	25	1

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iv) Jitter

The variation in delay between packets that occurs on the network is called jitter. The high jitter value is caused by the variation of traffic loads and the large collision between packets (congestion), which can cause the QoS value to decrease [13]. Jitter can be calculated by the following equation:

$$\text{Jitter} = \frac{\text{Total delay variation}}{\text{Total packets received}} \quad (4)$$

The jitter category can be seen in Table 4 [13].

TABLE IV
JITTER CATEGORY

Category	Jitter (ms)	Index
Excellent	0	4
Good	0 s/d 75	3
Medium	76 s/d 125	2
Bad	125 s/d 225	1

B. Customer Satisfaction Index

Satisfaction is the level of the state that someone feels (happy or disappointed) from comparing the results and expectations of a product [15]. The label used in summarizing the set of actions (actions) observed on a product or service is a term for customer satisfaction [16]. From the experts' statements, customer satisfaction is the response shown after comparing the perceived perceptions (performance) with the interests (expectations) of the customer. If the perception (performance) is felt to exceed the interests (expectations), the customer is very satisfied. If appropriate, they will feel satisfied, but on the contrary, if the perception (performance) is less than the interest (expectation), the customer feels less satisfied or even dissatisfied [17].

The customer satisfaction index is the level of customer satisfaction obtained between quantitative and qualitative measurement results, obtained from comparing interests (expectations) and perceptions (performance) [18]. The values and criteria of the CSI can be seen in Table 5 [19].

TABLE V
CRITERIA OF CSI

Index Value (%)	CSI Criteria
81,00 - 100,00	Very Satisfied
66,00 – 80,99	Satisfied
51,00 – 65,99	Quite Satisfied
35,00 – 50,99	Less Satisfied
0,00 – 34,99	Not Satisfied

III. RESEARCH METHODS

A. Bandwidth Management

Bandwidth on the network can be adjusted or shared according to the method specified. In this study, there are two methods used to manage or share bandwidth, namely the HTB and CBQ methods.

i) HTB Method

As the name implies, the HTB method uses tokens to control bandwidth on the network. The working principle of the HTB method is that incoming packets are classified according to a predetermined portion. Furthermore, scheduling is done on the packet. There are two purposes of scheduling, namely controlling packet delay and link sharing. The scheduling mechanism includes first come first serve, priority scheduling, weighted fair queue, and earliest deadline. Each node uses a token and bucket for bandwidth sharing. Token on the HTB system is divided into root class, interior class, and leaf class. The packet will be sent to the output port when it gets a token from the leaf class. And leaf classes can borrow excess bandwidth from the root class. More details can be seen in Figure. 1 [20], [21], [22].

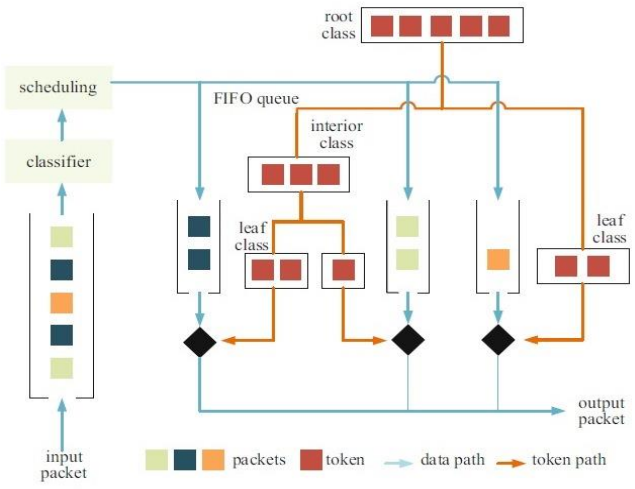

Figure 1: HTB Method

ii) CBQ Method

In the CBQ method, the incoming packet is divided into several predefined classes. There are two schedulers in the CBQ method, namely link-sharing scheduler and general scheduler. Each scheduler has different functions. The link-sharing scheduler ensures that the distribution of bandwidth long the network is correct.

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Meanwhile, the general scheduler has the task of selecting packets to be sent by considering the constraints required on the network. In addition, the general scheduler implements a queue priority mechanism that allows it to define different service levels for the class of a packet. For more details, it can be seen in Figure. 2 [23]

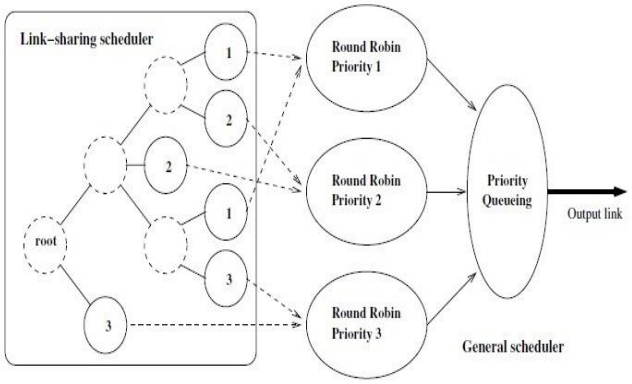

Figure. 2: CBQ Method

B. Steps To Obtain Customer Satisfaction

Customer satisfaction is used to complete the results of the network performance that has been applied to the HTB and CBQ methods. The qualitative descriptive method is obtained through the user's response to the network performance that has been implemented by both methods. With this method, it is necessary for users to determine the level of customer satisfaction with the network that has been implemented with the HTB and CBQ methods. The level of customer satisfaction is obtained by distributing questionnaires to users. Furthermore, the user answers all the questions contained in the questionnaire. The results of the answers to the questionnaire are then processed and analyzed so that the customer satisfaction index is obtained. The steps have taken in this process are as follows:

- Designing bandwidth management using HTB and CBQ methods
- Calculating the average value of the research variables, namely the Quality of Service parameters, including throughput, delay, packet loss, and jitter. As well as designing a questionnaire and validating the questionnaire instrument before it is used in the study.
- Distributing questionnaire instruments with sampling techniques to the respondents. The respondents used are 80 employees who are connected to a LAN network.
- Perform calculations on the results of the questionnaire.
- Analyze the results of the questionnaire and linked to the CSI criteria (see Table 5)

IV. Results And Discussion

Network performance monitoring has a function to measure data packet traffic information and analyze network traffic on the websites www.ecampuz.undhirabali.ac.id (Dhyana Pura University Campus) and www. gmail.com. Measurements are made based on the division of time, namely busy hours and normal hours. The busy hour is at 08.00-12.00 WITA and 13.00-16.00 WITA. and the normal hour at 16.00-20.00 WITA. This measurement was carried out by the HTB method for 3 consecutive days and continued with the CBQ method the next day for 3 consecutive days as well.

Dhyana Pura University campus has four buildings named building A, B, C, and building D, which have a centralized internet access configuration in one place, which is named Information and Communication Technologies (ICT) which is located in building B with a bandwidth of 20 Mbps. The network topology used is the extended star topology, shown in Figure. 3.

In Figure. 3, it can be explained that the local network on the Dhyana Pura University campus is directly connected to the ISP modem. From the main router to the main switch and connected to the switches in each room. The ethernet cable is directly connected to the router and the main switch on the server. The ethernet cable used is an ethernet cable type UTP (Unshield Twisted Pair) with the Cat 6 category. While the ethernet cable used to connect to each client with a total of 80 computers uses an ethernet cable type UTP (Unshield Twisted Pair) with the Cat 5 category. The distribution of 80 computers in each room and the distribution of bandwidth can be seen in Table 6.

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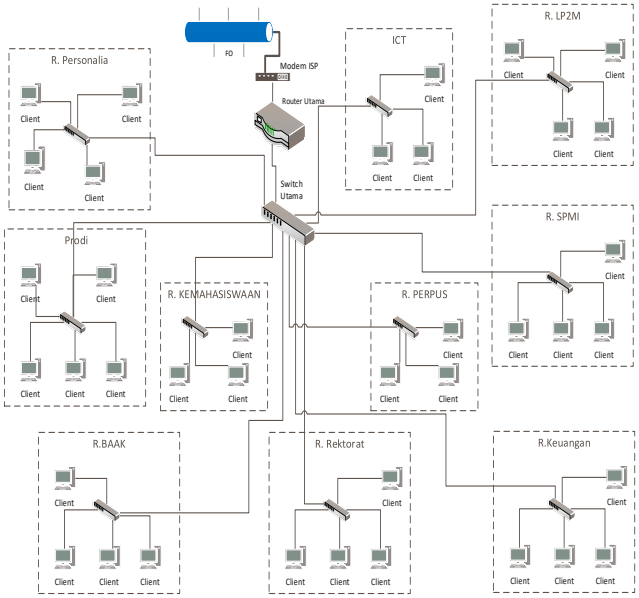

Figure 3: Network topology in Dhyana Pura University

TABLE VI
LIST OF PCS CONNECTED TO THE INTERNET NETWORK

No	Switch Location	Number of PC	Bandwidth	
			Limit At (Kbps)	Max Limit (Kbps)
1	ICT	4	256	1024
2	Finance	4	256	1024
3	BAAK	5	256	1024
4	Rectorate	3	256	1024
5	Staffing	4	256	1024
6	Library	3	256	1024
7	Department	46	256	1024
8	SPMI	3	256	1024
9	LP2M	5	256	1024
10	Student affairs	3	256	1024
Amount		80	20 Mbps	

To measure the flow of data packet traffic on the internet network using the software Axence NetTools [24] and Biznet Speed Test [25].

Through the Axence NetTools software, network performance is obtained, namely throughput, delay, packet loss. Meanwhile, with the Biznet Speed Test software, the network performance is obtained, namely jitter.

A. QoS Analysis Using HTB Method

i) Throughput

The results of the throughput measurement were carried out using the HTB method for each website. These results are then categorized according to the TIPHON standard which can be seen in Table 7.

TABLE VII
THROUGHPUT MEASUREMENT USING THE HTB METHOD

Website	Average (Kbps)	TIPHON
www.ecampuz.undhirabali.ac.id	100,1	Excellent
www.gmail.com	42,1	Medium

ii) Delay

The results of the delay measurement were carried out using the HTB method for each website. These results are then categorized according to the TIPHON standard which can be seen in Table 8.

TABLE VIII
DELAY MEASUREMENT USING THE HTB METHOD

Website	Average (ms)	TIPHON
www.ecampuz.undhirabali.ac.id	28	Excellent
www.gmail.com	35	Excellent

iii) Packet Loss

The results of the packet loss measurement were carried out using the HTB method for each website. These results are then categorized according to the TIPHON standard which can be seen in Table 9.

TABLE IX
PACKET LOSS MEASUREMENT USING THE HTB METHOD

Website	Average (%)	TIPHON
www.ecampuz.undhirabali.ac.id	1	Excellent
www.gmail.com	1	Excellent

iv) Jitter

The results of the jitter measurement were carried out on the HTB method for each website. These results are then categorized according to the TIPHON standard which can be seen in Table 10.

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TABLE X
JITTER MEASUREMENT USING THE HTB METHOD

Website	Average (ms)	TIPHON
www.ecampuz.undhirabali.ac.id	2	Excellent
www.gmail.com	2	Excellent

Based on Table 7 to Table 10 shows that the network performance in the form of throughput, delay, packet loss, and jitter on the website www.ecampuz.undhirabali.ac.id is 100.1 kbps, 28 ms, 1%, and 2 ms, respectively. Meanwhile, the website www.gmail.com shows the network performance respectively, namely 42.1 kbps, 35 ms, 1%, and 2 ms. From the analysis of the network performance measurement results on the two websites with the HTB method, it can be seen that the results are different on the performance of throughput and delay. With these results, the performance of the internet network on the website www.ecampuz.undhirabali.ac.id has a better performance than the website www.gmail.com

B. QoS Analysis Using CBQ Method

i) Throughput

The results of the throughput measurement were carried out using the CBQ method for each website. These results are then categorized according to the TIPHON standard which can be seen in Table 11.

TABLE XI
THROUGHPUT MEASUREMENT USING THE CBQ METHOD

Website	Average (Kbps)	TIPHON
www.ecampuz.undhirabali.ac.id	82	Excellent
www.gmail.com	37	Medium

ii) Delay

The results of the delay measurement were carried out using the CBQ method for each website. These results are then categorized according to the TIPHON standard which can be seen in Table 12.

TABLE XII
DELAY MEASUREMENT USING THE CBQ METHOD

Website	Average (ms)	TIPHON
www.ecampuz.undhirabali.ac.id	106	Excellent
www.gmail.com	85	Excellent

iii) Packet Loss

The results of the packet loss measurement were carried out using the CBQ method for each website. These results are then categorized according to the TIPHON standard which can be seen in Table 13.

TABLE XIII
PACKET LOSS MEASUREMENT USING THE CBQ METHOD

Website	Average (%)	TIPHON
www.ecampuz.undhirabali.ac.id	6	Excellent
www.gmail.com	4	Excellent

iv) Jitter

The results of the jitter measurement were carried out on the CBQ method for each website. These results are then categorized according to the TIPHON standard which can be seen in Table 14

TABLE XIV
JITTER MEASUREMENT USING THE CBQ METHOD

Website	Average (ms)	TIPHON
www.ecampuz.undhirabali.ac.id	7	Excellent
www.gmail.com	7	Excellent

Based on Table 11 to Table 14, the network performance in the form of throughput, delay, packet loss, and jitter on the website www.ecampuz.undhirabali.ac.id is 82 kbps, 106 ms, 6%, and 7 ms, respectively. While the website www.gmail.com has network performance, respectively, namely 37 kbps, 85 ms, 4%, and 7 ms. From the analysis of the network performance measurement results on the two websites using the CBQ method, it can be seen that there are four network performances but only the jitter performance has the same value. Meanwhile, the other three network performances have different values and show varying performance. With these results, for the throughput performance, the internet network has a better performance on the website www.ecampuz.undhirabali.ac.id compared to the website www.gmail.com. For the performance of delay and packet loss, the internet network has worse performance on the website www.ecampuz.undhirabali.ac.id compared to the website www.gmail.com. Meanwhile, the jitter performance of the two websites has the same performance.

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C. Comparative Analysis of QoS with HTB and CBQ methods

Based on the results of the average value of each parameter for the two methods, it can be concluded that the performance of the internet network on each parameter for busy and normal network conditions at Dhyana Pura University can be seen in Table 15.

TABLE XV
COMPARISON OF THE RESULTS OF THE HTB AND CBQ METHODS

Method	Network Condition	Parameter of QoS			
		Throughput (Kbps)	*Delay (ms)*	*Packet loss (%)*	*Jitter (ms)*
HTB	Busy hour	59,5	27,5	1,3	2,2
	Normal hour	82,7	26,7	1	2,9
	Average	71,10	27,10	1,15	2,55
CBQ	Busy hour	59,7	213,3	6,42	7,3
	Normal hour	59,5	73,1	2	4,6
	Average	59,60	143,2	4,21	5.95

Based on Table 15, the results of measuring the performance of the LAN network at Dhyana Pura University in the TIPHON standard using the HTB method obtained an average value for the QoS parameter. The throughput value is 71.10 Kbps (good), the delay is 27.10 ms (excellent), the packet loss is 1.15% (excellent), and the jitter is 2.55 ms (excellent). While the performance of the LAN network using the CBQ method obtained an average value of QoS parameters, namely throughput is 59.60 bps (good), delay is 143.2 ms (excellent), packet loss is 4.21% (good), and jitter is 5.95 ms (excellent).

From the analysis of the measurement results as seen in Table 15, the four internet network performances using HTB and CBQ methods for busy and normal hour have different values. The difference in the results of the network performance shows that the performance of the internet network with the HTB method has better performance than the CBQ method.

D. Customer Satisfaction Test Results

The results of the questionnaire were conducted to obtain data on user satisfaction with internet network services using the HTB and CBQ methods at Dhyana Pura University. Network performance is measured to get the average value of user satisfaction based on the parameters of QoS, namely throughput, delay, packet loss, and jitter.

The results of the Customer Satisfaction Index (CSI) analysis on respondents who use internet network services using HTB and CBQ methods which include the performance of throughput, delay, packet loss, and jitter can be seen in Figure. 4.

From Figure. 4, it shows that overall internet network users using the HTB method obtained an average customer satisfaction index value of 77.14%. In other words, internet network users with the HTB method already feel satisfied with the performance of the internet network provided. This can be seen from the results of the questionnaire that has been conducted for the performance of throughput is 80.14%, the delay is 76.38%, packet loss is 75.89%, and jitter is 76.16 ms. While the performance of the internet network using the CBQ method, the average customer satisfaction index is 64.49%. This result means that internet network users using the CBQ method are included in the quite satisfied criteria. This can be seen from the results of the questionnaire that has been conducted for the performance of throughput is 61.59%, the delay is 67.94%, packet loss is 72.23%, and jitter is 56.22%. Thus, the level of customer satisfaction with internet services using the HTB method is higher than the CBQ method.

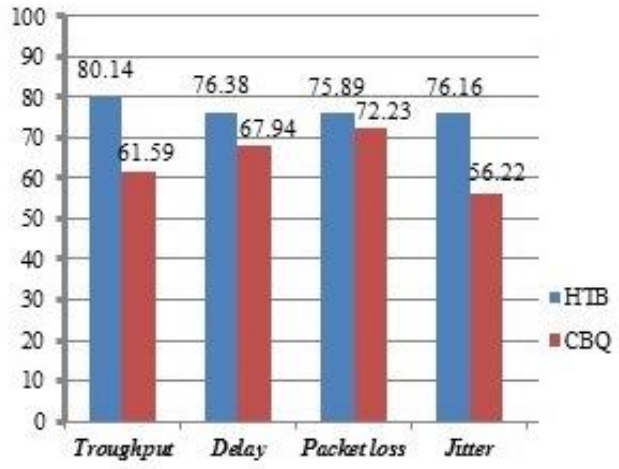

Figure. 4: CSI value and QoS parameters with HTB and CBQ methods

V. CONCLUSION

Based on the results of the analysis of internet network performance using HTB and CBQ methods and customer satisfaction, it can be concluded that first, the performance of the internet network using the HTB method on both websites shows that for throughput and delay performance is that the website www.ecampuz.undhirabali.ac.id is better than the website www.gmail.com. While the performance of packet loss and jitter obtained the same results.

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Second, the performance of the internet network with the CBQ method for both websites shows that for throughput performance the website www.ecampuz.undhirabali.ac.id is better than the website www.gmail.com, for delay and packet loss performance the website www.gmail.com is better than www.ecampuz.undhirabali.ac.id, and for jitter performance of the two websites the same results are obtained. Third, the results of the comparison of the performance of the internet network for busy and normal hour with the HTB and CBQ methods show that the network performance with the HTB method is better than the CBQ method for the four parameters of QoS. Lastly, the results of the questionnaire on customer satisfaction for internet network performance using the HTB method showed that the mean value of the customer satisfaction index was 77.14% (satisfied criteria). In contrast, with the CBQ method, the average value of the customer satisfaction index is 64.49% (quite satisfied criteria). So that the level of customer satisfaction with internet services using the HTB method is higher than the CBQ method.

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