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Comparative performance analysis of different queuing techniques for campus area network

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ABSTRACT

A quality network infrastructure is a user demand for the increment of traffic nowadays. Due to data traffic congestion, a network's service quality cannot fulfill the user demand, especially for streaming-type traffic. For this, an appropriate queuing method can be a convenient solution for network congestion at the time of picking traffic load. In this paper, a simulation was conducted using the OPNET application to examine the feasibility of three types of queuing methods, namely first in first out (FIFO), priority queuing (PQ), and weighted fair queuing (WFQ). During the simulation, several important parameters such as delay, throughput, and response time are considered as performance metrics and compared among four types of applications as file transfer protocol (FTP), hypertext transfer protocol (HTTP), voice over internet protocol (VoIP), and video conferencing. According to the result, it is observed that WFQ provides comparatively improved results than PQ and FIFO.

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1. INTRODUCTION

With economic and technological advancements, especially those related to digital content that can be accessed online, computer networks no longer only serve data, but also include voice, picture, and video services [1]. The increase that occurs is not only in the type of service, but also the number of users is getting bigger due to the price of the device which tends to be cheap. This of course adds to the burden of network infrastructure.

The campus network is an implementation of a computer network that aims to serve various academic activities on campus [2]. Like other IP-based computer networks, campus networks have also been widely used to access various content services but with a much larger number of users, so it can be said that the campus network infrastructure is almost close to the infrastructure of the mentropolitant area network (MAN). The campus network plays an important role in various academic activities for students and lecturers, including web services, voice and video services, and administrative services for campus staff. This causes the campus network to work very hard, especially at busy times. If this is exacerbated by limited bandwidth, congestion will be very vulnerable to occur, disrupting all network activities.

Congestion in communication network services occurs when the network's bandwidth is insufficient to handle a sudden increase in data traffic [3], [4]. Network congestion often occurs on campus networks because of the large number of users and the variety of content accessed [5], [6]. This will be a very frightening specter, especially on streaming services such as video conferencing [7].

Quality of service (QoS) is a mechanism that allows regulation that aims to prevent congestion in the flow of data traffic and at the same time improve the grouping of data traffic flows and can work on all types of networks such as asynchronous transfer mode (ATM), Ethernet, Wi-Fi, and all other IP based networks. This can happen because QoS works by setting the priority level for each type of data flow and data will be passed based on that priority [8], [9]. In its application to the network, QoS is implemented using several different queuing techniques.

This study was conducted to test the ability of three queuing methods, namely first in first out (FIFO), priority queuing (PQ), and weighted fair queuing (WFQ) in preventing congestion on the campus network. The topology used is the original campus network topology. The campus network used is the network from Tadulako University in Indonesia, precisely in the province of Central Sulawesi. The campus network at Tadulako University itis used for various activities, academic activities, administrative services, communication between agencies, and communication with outside parties. The network is simulated using the OPNET Modeler application. OPNET modeler is a simulation program that can design, measure performance, and design a communication network model so that it is often used in the academic world, especially those related to communication networks. OPNET can simulate various network technologies such as internet protocol (IP), global system for mobile (GSM), WiMax, and Zigbee networks [10].

The simulation is carried out by running data traffic types from four types of applications that are often used at Tadulako University, namely hypertext transfer protocol (HTTP), file transfer protocol (FTP), voice over internet protocol (VoIP), and video conferencing. The parameters used to test the performance of the three queuing methods are, end-to-end packet delay and traffic loss for VoIP and video conference, upload response time for FTP, and object response time and page response time for HTTP services.

2. LITERATURE REVIEW

Research related to QoS is not something new. There have been several previous studies that can be used as a reference. Xue *et al.* [11] in his research carried out a combination of PQ and WFQ techniques in dealing with campus networks. Through a combination of these two techniques, the amount of packet loss, jitter and delay can be minimized. Other research related to QoS was also conducted [12]. The research he did was using a simulation on the OPNET modeler 14 application based on the wide area network network. By using the modified WFQ technique using time stamp parameters, real-time application content can be maximized. Other research has also been carried out [13]. His research aims to test QoS techniques in a 5G network environment using three QoS techniques, namely FIFO, PQ, and WFQ. Based on the simulations carried out involving various types of data traffic, it is known that PQ is able to provide the best performance.

3. QUEUING METHODS

Every router, whether placed in the demilitarized zone (DMZ), backbone, or endpoint area is equipped with QoS capabilities [14]. QoS is the ability to queue data traffic based on a predetermined priority of a queuing technique. This queuing technique will regulate how the received data packets are accommodated before being transmitted and determine which packets are received and transmitted and which packets must be discarded [15]. The three queuing techniques commonly used are FIFO, PQ, and WFQ.

3.1. First in first out

First in first or FIFO out or what is commonly abbreviated as FIFO is a queuing technique that adheres to the principle of first-come-first-served: those who come next will wait until those who arrive first have been served, as is often the case with people queuing to be served. FIFO is the most basic queuing technique and is activated by default on some routers [16]. FIFO generalizes all types of incoming data packets and does not give priority to these data packets. This makes FIFO less suitable for handling sensitive data packets such as streaming files so it tends to be avoided on networks that are very busy with various types of content on them [17]. The concept of FIFO can be seen in Figure 1.

3.2. Priority queuing

Priority queuing or PQ is a refinement of FIFO. The process itself is as follows, the router will mark each data packet it receives with the aim that the router can carry out a more detailed queuing process. After all data packets have been marked, the router will see the priority level it has (set by the network engineer) to determine which data packets are prioritized to be passed first [18]. Then the router will pass data packets with the highest priority to the lowest based on the priority level set and the sign on each data packet. The advantage of this method is that it can handle data packets with a very high level of sensitivity to be immediately sent to the destination, but it has the disadvantage that data packets classified as low priority will have a low quality of service. The concept of PQ can be seen in Figure 2.

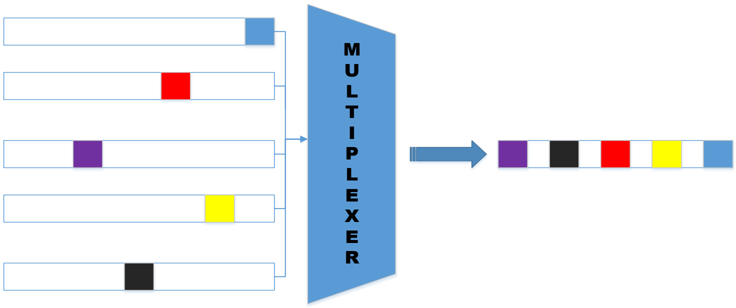


Figure 1. Illustration of first in first out

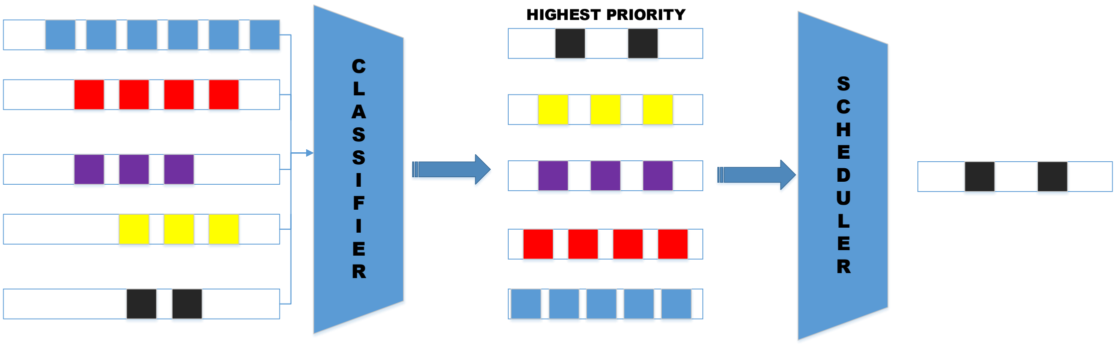


Figure 2. Illustration of priority queuing

3.3. Weighted fair queuing

Weighted fair queuing or WFQ was developed by Lixia Zhang, Alan Demers, Srinivasan Keshav, and Scott Shenke in 1989. WFQ works by assigning weights (determined by network engineers) for each type of data packet [19]. This weight value will determine how large a data packet will be passed at one time. This is so that all types of data packets can be passed proportionally without compromising the quality of service [20]. The concept of WFQ can be seen in Figure 3.

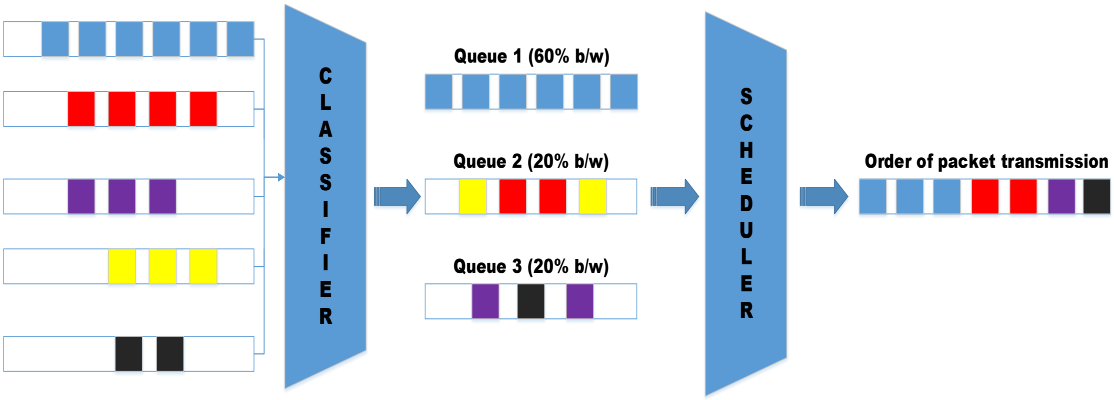


Figure 3. Illustration of weighted fair queuing

4. EXPERIMENTAL DESCRIPTION
4.1. Network topology

This simulation takes the topological model used by Tadulako University as a campus network model. The topology of the campus network itself can be seen in Figure 4. The topology in Figure 4 shows that the entire faculty network is connected to a core switch that is connected to a core router located in the university data center. The core router also serves to connect all existing local area network (LAN) networks in the university environment with servers in the data center room. The network topology of Tadulako University can be seen in Figure 4.

The entire network in the faculty is further divided into several networks in each faculty can be seen in Figure 5 and the network at the department level can be seen in Figure 6. Figure 6 also shows that each department has an internal computer network used for administrative and laboratory purposes, a Wi-Fi network used by students for lectures, and a network VoIP used for internal communication by related parties. All departments are connected by a switch located in the main faculty building which is connected to a core switch located in the data center room

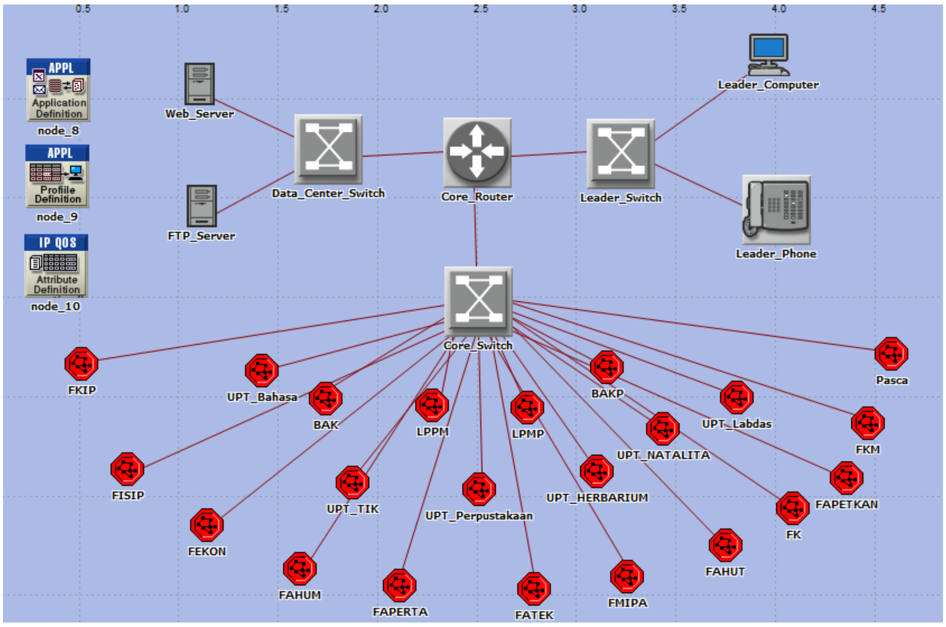


Figure 4. Tadulako University network topology at OPNET

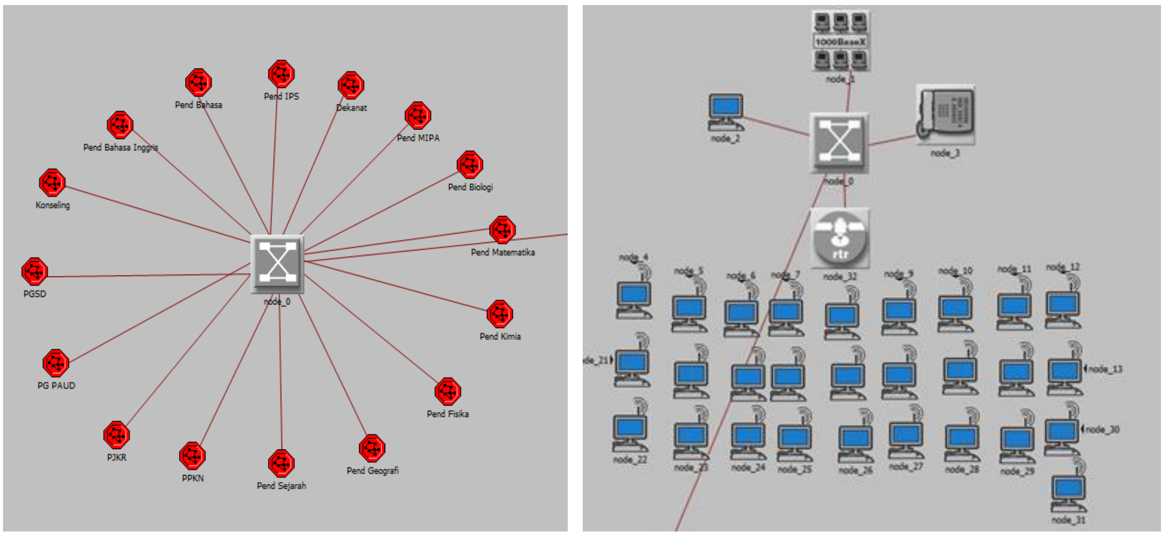


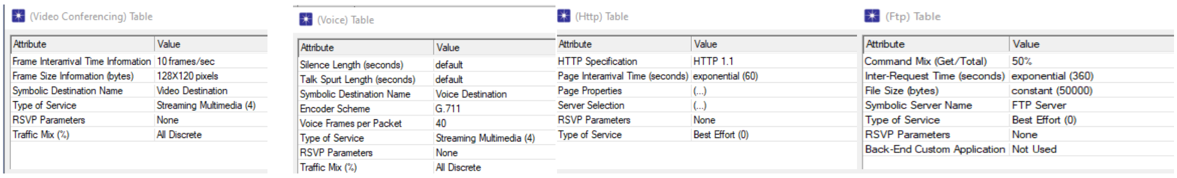
Figure 5. Networking at the faculty level and the department level

4.2. Simulation parameter

The tests carried out in this simulation use the types of content that are often used at Tadulako University, namely FTP, HTTP, video conferencing, and VoIP. These four types of content will be run simultaneously in a simulation that is adapted to the actual situation on the campus network, precisely on the Tadulako University network with high data traffic load conditions. The parameters used to measure the performance of each queuing method are as follows:

a) Packet end-to-end delay: This parameter refers to the time it takes to transmit data from one user endpoint to another. This can be measured as either a one-way or round-trip delay for video conferencing and VoIP services. This statistic records data from all the nodes in the network [21].
b) Traffic received: Average bytes per second forwarded to all applications by the transport layers in the network [22].
c) Jitter: In VoIP technology, jitter refers to the delay in receiving voice data packets. This delay affects voice quality and data transmission [23].
d) Upload response time: Time elapsed between sending a file and receiving the response. Because the process that often runs on the Tadulako university network is sending files to the server and not the other way around, the parameter used is the upload response time [24].
e) Object response time: Specifies response time for each inlined object from the HTML page [25].
f) Page response time: Specifies the time required to retrieve the entire page with all the contained inline objects [10].

All parameter values used will be analyzed to determine what queuing method is suitable for use on campus networks that have very high data traffic loads. In the OPNET modeler application, the priority level of the application is also adjusted to the level of needs in the university's network which can be seen in Figure 6. In video conferencing priority is placed on a multimedia streaming level, VoIP priority is placed on interactive multimedia, while HTTP and FTP are placed on best effort priority, in other words, VoIP will have the highest priority to be passed first when the data traffic load is high. However, the priority rule will not apply to the FIFO method because FIFO will skip the type of data traffic that arrives first regardless of the type of packet. This priority rule can only be used when the simulation uses the PQ and WFQ methods. The application and parameter settings of OPNET can be seen in Figure 6.


(Video Conferencing) Table

Attribute	Value
Frame Interarrival Time Information	10 frames/sec
Frame Size Information (bytes)	128X120 pixels
Symbolic Destination Name	Video Destination
Type of Service	Streaming Multimedia (4)
RSVP Parameters	None
Traffic Mix (%)	All Discrete

(Voice) Table

Attribute	Value
Silence Length (seconds)	default
Talk Spurt Length (seconds)	default
Symbolic Destination Name	Voice Destination
Encoder Scheme	G.711
Voice Frames per Packet	40
Type of Service	Streaming Multimedia (4)
RSVP Parameters	None
Traffic Mix (%)	All Discrete

(Http) Table

Attribute	Value
HTTP Specification	HTTP 1.1
Page Interarrival Time (seconds)	exponential (60)
Page Properties	(...)
Server Selection	(...)
RSVP Parameters	None
Type of Service	Best Effort (0)

(Ftp) Table

Attribute	Value
Command Mix (Get/Total)	50%
Inter-Request Time (seconds)	exponential (360)
File Size (bytes)	constant (50000)
Symbolic Server Name	FTP Server
Type of Service	Best Effort (0)
RSVP Parameters	None
Back-End Custom Application	Not Used

Figure 6. Application settings on OPNET

5. RESULTS ANALYSIS

After setting up the application on OPNET, the next process is a simulation of the three queuing methods. The simulation on the network with a duration of three minutes was carried out three times by comparing each result obtained by the three queuing methods. The test results and analysis will be divided into three parts as follows.

5.1. Video conference

Video conferencing service is the second priority service in this simulation. Video conferencing simulations are carried out by running video conferencing applications between computers from the central leadership and computers at each head of administrative institutions and leaders of faculties and departments. Simulations performed on the three queuing methods generate traffic received values, the results of which can be seen in Figure 7.

From the graph shown in Figure 7, it can be seen that PQ and WFQ give better results when compared to FIFO. This parameter relates to the amount of data traffic lost during the data transmission process. By looking at the graph, it can be seen that FIFO is experiencing significant data traffic losses. To find out who is the best in this test, it can be seen in the next parameter, namely packet end-to-end delay. Based on the simulation, the average end-to-end packet delay value is 223,444 ms for FIFO, 223,119 ms for PQ, and 223,005 ms for WFQ. It is clear that although the difference is small, WFQ can produce a better end-to-end delay value than PQ and FIFO in handling video conference data traffic.

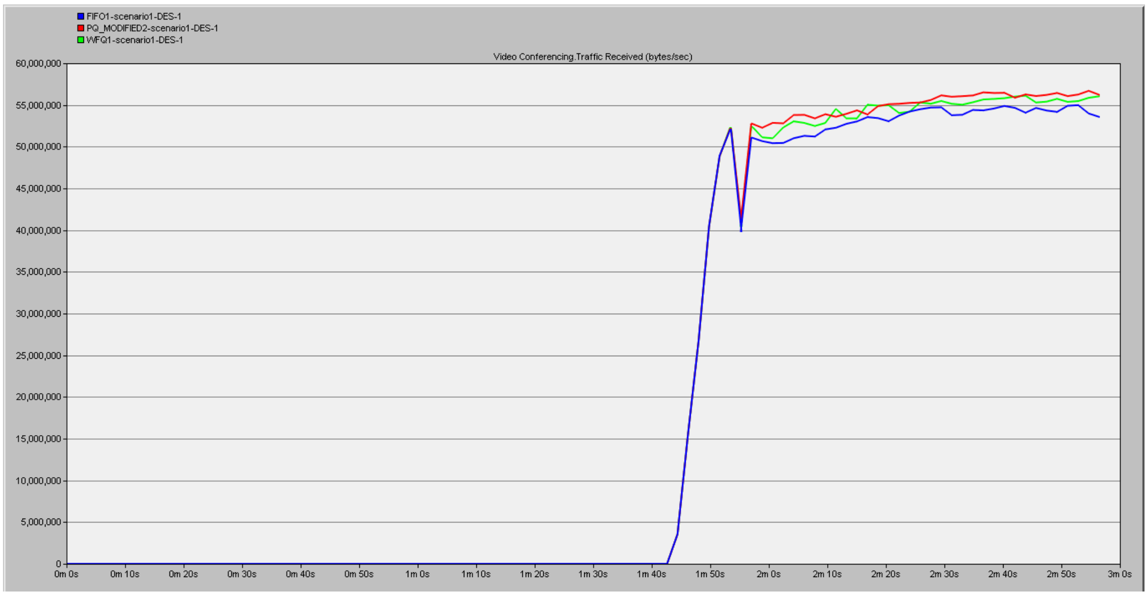


Figure 7. Graph of traffic received on the video conference

5.2. Voice over internet protocol

VoIP is the service with the highest priority in this simulation. VoIP simulation is done by running VoIP devices in each agency and VoIP in the central leadership room. The simulation results in the form of the received traffic values can be seen in Figure 8.

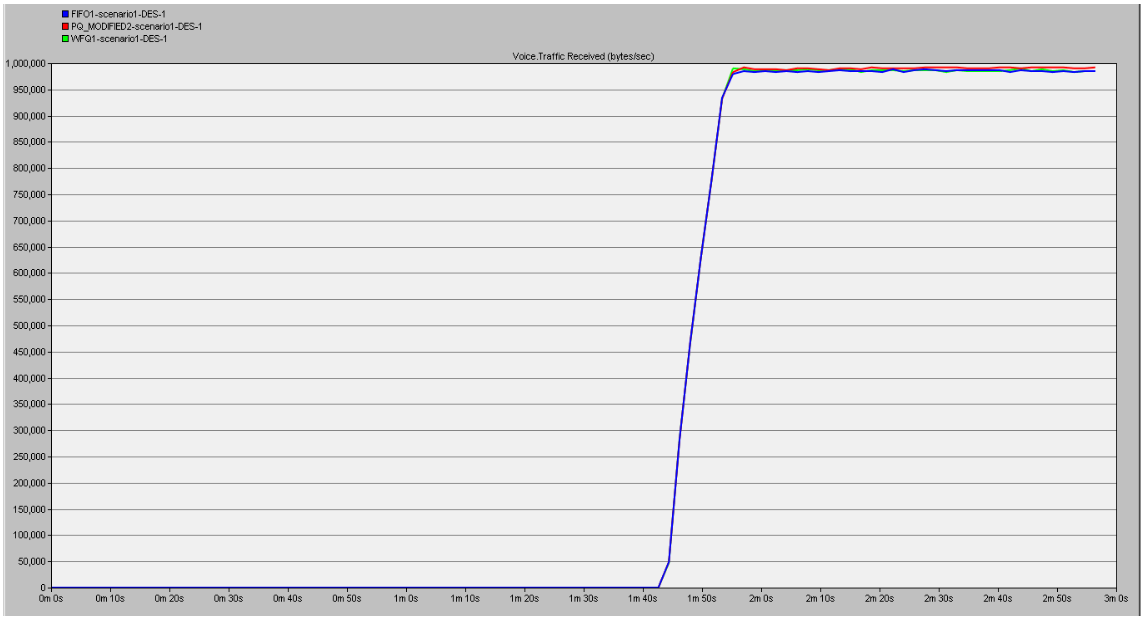


Figure 8. Graph of traffic received on VoIP

Based on the graph of the simulation results, it can be seen that the three queuing methods have almost equal results. Even if there is a difference in value, the value between the three is quite small. However, to see the quality of the resulting service, the Jitter value can be used. The results of Jitter on the three queuing methods can be seen in Figure 9.

Based on the graph in Figure 9, it can be seen that FIFO has a very high maximum Jitter value when compared to PQ and WFQ and indicates poor voice service quality. This of course shows that FIFO is not recommended to handle streaming and interactive data traffic. The graph also shows the superiority of PQ over WFQ although the value is not significant.

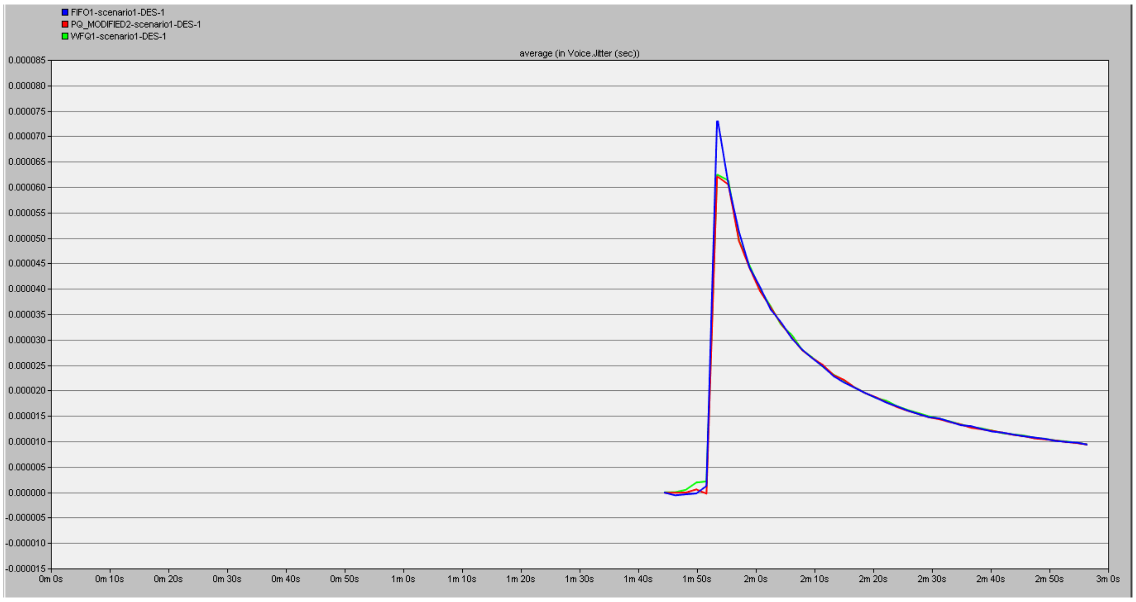


Figure 9. Graph of Jitter on VoIP

5.3. File transfer protocol

Even though FTP is not a priority service in this simulation, it should be noted that the test results are quite widely used, especially at Tadulako University. This service is usually used to upload website files to university servers. To see the performance produced by the three queuing methods, the response time parameter is used, the results of which can be seen in Figure 10. From the graph in the figure, it can be seen that WFQ has a very striking difference compared to PQ and FIFO, it can be seen from the very low response time value. when compared to PQ and WFQ. This is understandable because WFQ can divide the priority load evenly among all data traffic. In contrast, PQ only focuses on traffic with the highest priority [25]. Like the previous test, FIFO has the highest maximum response time compared to PQ.

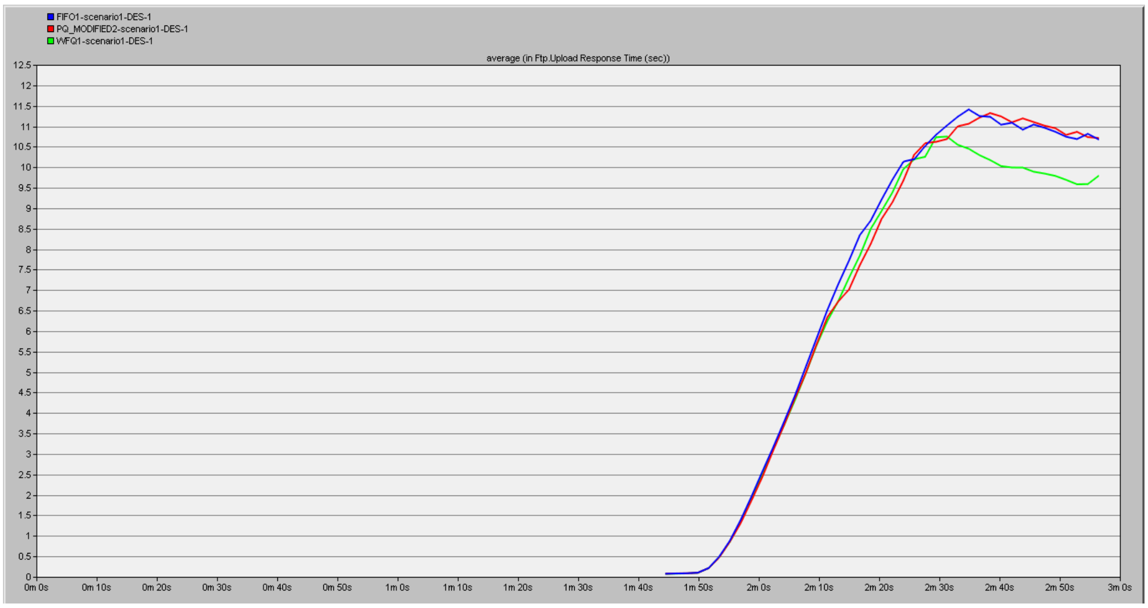


Figure 10. Graph of response time on FTP

5.4. Hypertext transfer protocol

Like FTP, HTTP is a service that is not prioritized in this simulation. However, HTTP is the service with the largest number of users in a campus environment so its quality cannot be ignored. To see the quality of service provided by the three queuing methods, the object response time and page response time parameters are used and the results can be seen in Figures 11 and 12. Based on the object graph reading and page response time, it is known that WFQ can provide a significant value compared to PQ and FIFO. This is because WFQ will try to divide the queue evenly to all traffic, even to traffic with low priority. This is different when compared to PQ which prioritizes traffic with the highest priority. Of course, this increase affects the value of object response time and page response time from PQ.

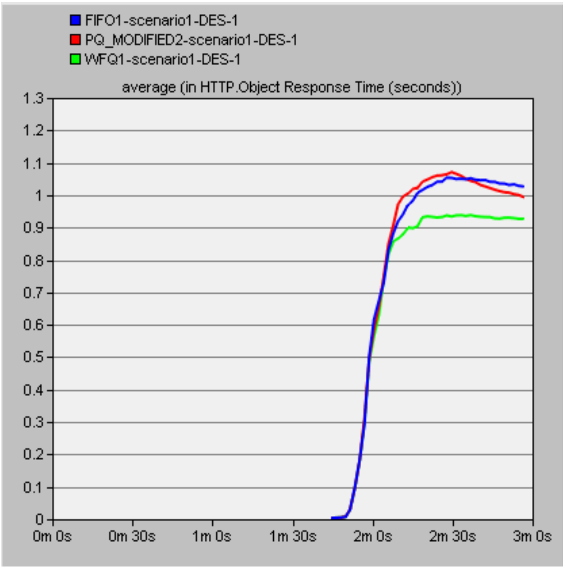


Figure 11. Object response time

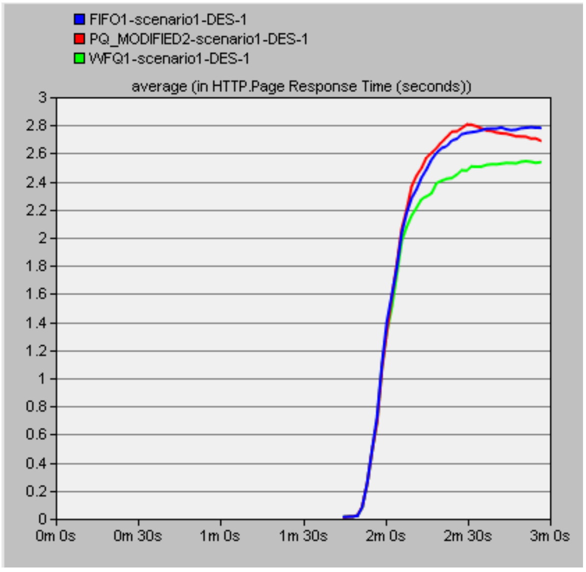


Figure 12. Page response time

6. CONCLUSION

The purpose of this paper is to find the best queuing technique that can handle all types of data traffic on the campus network, whether it is traffic with high priority or not. Based on the results of the simulations carried out along with the existing graphs, it can be concluded that WFQ can provide an even distribution of traffic load to all data traffic that passes through the network. Although highly sensitive data traffic, such as VoIP, and PQ can be superior, WFQ traffic as a whole can be superior, so for general use, WFQ is recommended. PQ can be used when data traffic is heavy and has a highly sensitive and high-priority type of data traffic. FIFO, as seen in all test results, is not recommended for handling high data traffic loads.

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