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Modelling the Performance of Class-Based Weighted Fair Queue Using OPNET

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ABSTRACT

Congestion control and internet network resources management are complex and critical issues in a high-speed packet switch data network, due to the emergence growth of modern multimedia streaming services. The increasing number of computer users in various organizations and institutions of higher learning have spurred a great deal of research on network traffic control. Network administrators are facing the challenges of providing efficient services that can satisfy user requirements. This research study proposed queuing algorithm based on class-based weighted fair queue scheme to complement congestion. Network simulation environment are designed and modeled using OPNET simulation software in-order to overcome the limitation of the traditional queuing approach. Various simulations scenarios are conducted. Analysis comparison with first-in-first-out and priority queue is recorded. And also, various network traffics such as: HTTP, video conferencing and voice applications among others are considered. From the graphical results obtained clearly shows that the overall applications services performances optimize significantly. In terms of the throughput, packet loss and queuing delay, the algorithms performs excellently compared with the FIFO and priority queue. This paper examines the implication of queuing scheduling algorithms on an IP router. It also outlines the effectiveness of the proposed algorithm in managing network resources during the period of congestion.

KEYWORDS

Congestion Control, Scheduling Algorithm, Simulation Model, Traffic Control, OPNET Simulator.

1 INTRODUCTION

Internet network traffic growth rapidly, due to the introduction and development of modern multimedia application and streaming services. Efficient services performances are highly demanded for both industries and universities to satisfy internet user requirements. Memory management implemented on a buffer tried to avoid packets congestion. The, TCP congestion avoidance mechanism is not sufficient enough to provide better services in all circumstances. It uses the best effort model that only attempts to provide the required service without reliability. Admittedly, packets scheduling algorithms managed per flow bandwidth allocation for a fair and an efficient sharing of the network resources among various traffic classes and support quality of service. During packets transmission, queuing scheduling algorithm provides the minimal applications bandwidth guaranteed.

Network resources are highly demanded among various traffic classes. Advertently, real time applications consume much of the link bandwidth and buffer and starved non real time counterpart. Saturation of bandwidth and buffer degrades network performance. There is a need of a queuing scheduling algorithm in-order to complement congestion and enforce fairness in sharing of network resources. However, routers and switches use the traditional scheduling discipline to route traffic to the destination. In this study, class-based weighted fair queue algorithm is proposed and modeled to provide significant internet performance improvement.

Simulation-based study required a powerful network simulator for modeling the network environments and verification. According to [2] research study stated that simulation prevent over-utilization of resources and optimizes system performance. Among the simulation software available in the markets, OPNET modeler is the powerful application software oriented simulator that modeled all aspects of real time and distributed networks. It can serve as teaching tool in schools and has been widely used in modeling the abstracting behavior of real time network. It also involves in the design and development of various aspect of wireless network and data communications.

Various researches using simulation modeling has been done with OPNET [8], [9] [10]. The research study done by [8], constructed real enterprises network prototype and virtual OPNET simulation model. Also, explore the practical application of the models in university education. In [9] paper, proposed a bandwidth guarantee scheme using a class-based weighted fair queue scheduling algorithm implemented on a router. The study presented clearly that traffic classes met their minimum bandwidth requirements. Similarly, according to [10], study on modeling the performance of SOHO network. An investigation was carried out, and analysis results revealed that links data rate upgrades is not economically feasible. Consequently, there is a need of examining the system under study.

Rapid growth in the computer applications development added the complexity in network configuration and quality of service support. Limited network resources leads to the saturations of the buffer and bandwidth scarcity among traffic class. Dynamic internet access by different users within organizations make congestion controls an outstanding issue of consideration. Resources management and congestion control still remain an important area of study in data communication and distributed system.

According to [1], congestion control in packet switching networks, become a high priority in network design and researches due to ever-growing networks bandwidth and intensive applications. Thus, there is growing literature in the area, [3], [4], [5], [6], [7]. Admittedly, [6] of these have shown that congestion can be controlled at gateway through routing and queuing scheduling algorithm. The research study by [3], mentioned that priority of packets scheduling are based on the conditions that the delay sensitive real time packets as the highest priority and packets waiting for a specified time as the lowest priority. Also [5] research study, proposed a link-based fair aggregation technique for queuing scheduling at both the ingress and egress routers. In the [4] paper, simulated an analytical call admission control algorithm in heterogeneous wireless network. In the research study by [7], detailed the inaccuracy of the traditional traffic model like the Poisson’s model, under the bursty real network traffic condition. Hence, performance analysis based on these models can lead to a severe underestimation of packet delay or loss that can affect performance. As a result of that, the study introduces a new traffic model using OPNET Modeler based on hierarchical scheme of Bernoulli sources

Dynamic changes in networks and continuous growth in internet applications development are making congestion control problems a critical issue. However, these potential effects have to be observed and address. The main causes of congestion control in packet-switching network are saturation of network resources like: communication links, buffers and processors cycles. Adverse effects of congestion degrade performance.

In-order to overcome the immediate effects of congestion, we proposed a queue scheduling algorithm based on class-based weighted fair queue scheme. Discrete event simulation model environment are designed and developed. The proposed class-based weighted fair queue algorithm is implemented in a router.

Simulation scenarios results are recorded and analysis comparison is presented. Considering queuing delay, packet loss, traffic sent and received. Our proposed class-based weighted fair queuing algorithm shows performance improvements in comparison with the other traditional approach. In terms of the quality of service measures, the algorithm attained the highest level of expected throughput with low queuing delay. Consequently, the information presented in this paper examined the impacts of queuing scheduling algorithm in router. Also address the critical challenges faces by network administrator in sharing of network resources.

2 QUEUING ALGORITHMS

Emergence growth in high-speed packet switch network initiates the need of packet scheduling algorithms. Network is said to be congested when a link output-buffer cannot accommodate incoming packet. This effects, generates a long delay in a queue during transmission. Memory management aims to avoid network congestion. Meanwhile, packet scheduling algorithms monitors and control congestion. According to the research by [11], proposed packet queuing algorithm and also examines its implication in wireless network. Simulation results revealed significant performance improvement.

This section discusses some of the traditional queuing scheduling algorithm in-order to show the effectiveness of our proposed algorithm. Also, the details explanation of the algorithm is presented.

2.1 First-In-First-Out

The concept behind first-in-first-out is based on first come first serve mechanism. Packets are served in the queue buffer based on their arrival time. Due to the priority given to the first packet on arrival, other traffic classes waiting for service gets dropped instantly. In addition, a flow of traffic can be starved by other flows that have a higher traffic, as clearly illustrated in figure 1 below.

It is easy to implement and no added delay from the queues. Also, does not always make the best use of bandwidth. It is the simplest queuing algorithm implemented in most of the network routers and switches.

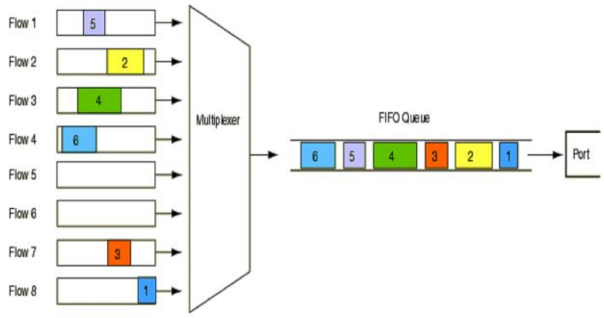


Figure 1. First-in-First-Out Queue

2.2 Class-Based Weighted Fair Queue

This packet scheduling discipline guarantees a minimal bandwidth to each class of service in a network. It uses the scheduling techniques of weighted fair queuing (WFQ), for assigning weight to different class of service. Priority is given to certain classes of traffic in the router. This scheme enforces fairness at which specific bandwidth is reserved in case if some classes have utilized their share. Further transmission can be done using the available bandwidth. In [9] study, details of bandwidth allocation, flow weight assignation and calculation of packets virtual finish time are presented. As shown in figure 2 below, is the classification and scheduling of an incoming packet to an output ports.

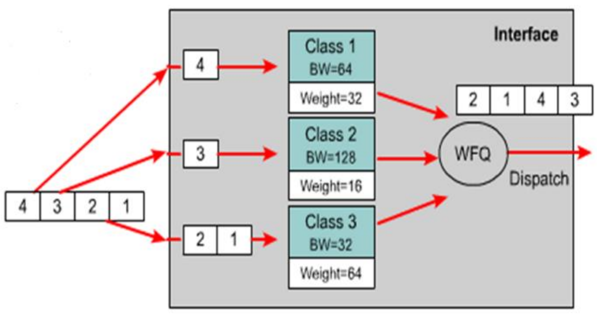


Figure 2. Class-Based Weighted Fair Queue [9]

2.3 General Processor Sharing

In this scheduling technique, packets in a queue are served using a flow timestamp approach of a processor cycle [9]. Early arrival packets have higher priority in service than late arrival ones. This queuing scheme works best when combined with the priority queue algorithm to allocate internet bandwidth. It is the basis of which the class-based weighted fair queue operates.

2.4 Priority Queuing

In priority queuing scheme, flows are queued using the following categories: high, medium, normal, and low. And within each priority, packets are managed in a FIFO manner. During transmission, higher priority packets are allows to cut to the front of the queue. It is the basis for a class of queue scheduling algorithms used to provide the quality of service support for real time application. As shown in figure 3 below is the illustration diagram indicating an incoming flow of traffic from the ingress port interface to the different classes of queue for transmission.

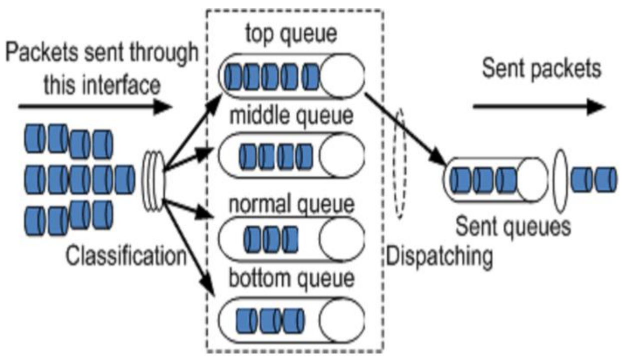


Figure 3. Priority Queue

3 Experimental Descriptions and Simulation

The simple Ethernet network is designed and constructed during the modeling of the class-based weighted fair queue algorithm, first-in-first-out and priority queue router. The network topological model illustrated in figure 4 below consists of four clients sending traffics to their servers via switches and routers.

In addition, all the nodes in the network are connected using 10 Mbps data link speed, with the exception of the potential bottleneck link between the routers A and B. Clients transmits HTTP, FTP, video and voice traffic to the HTTP & FTP server, voice and video server clients respectively.

Each client is properly configured to provide the required services for each traffic classes using the application configuration object. The application profile attribute is configured to supports the services of the applications. In the model, servers are configured to supports various applications services. The potential bottleneck links between routers has been configured globally using the IP QoS configuration to supports the routing of traffic classes in the network. During simulation discrete event statistic is collected and various scenario graphs are generated for analysis.

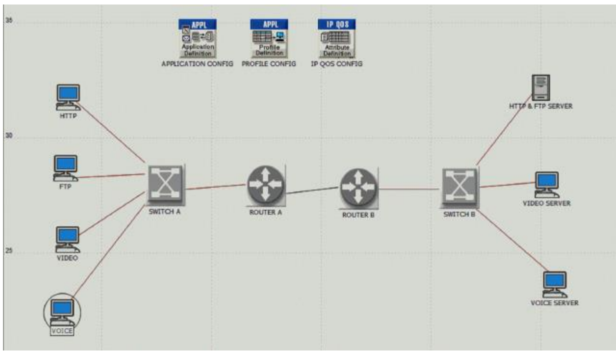
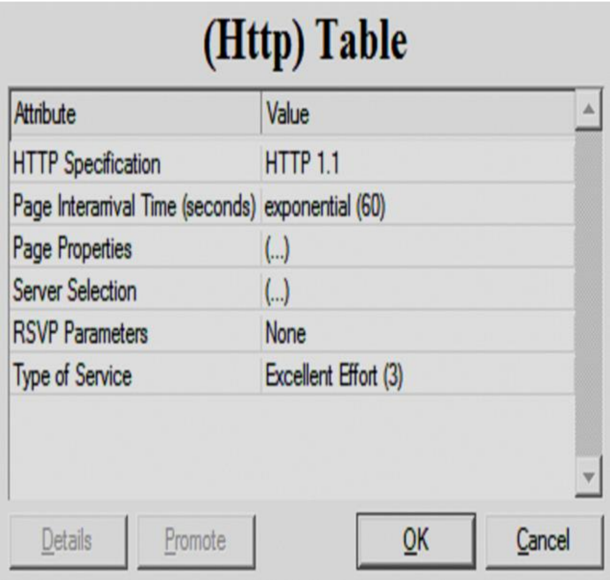


Figure 4. Simulation network model

3.1 Network Configuration

3.1.1 Configuring Network and Applications

The HTTP application is configured to support the excellent effort web services model using the application configuration attribute object. It page inter-arrival time is set to exponential 60 and constant 10 as the start time offset. Figure 5 below gives the details of the configuration process.

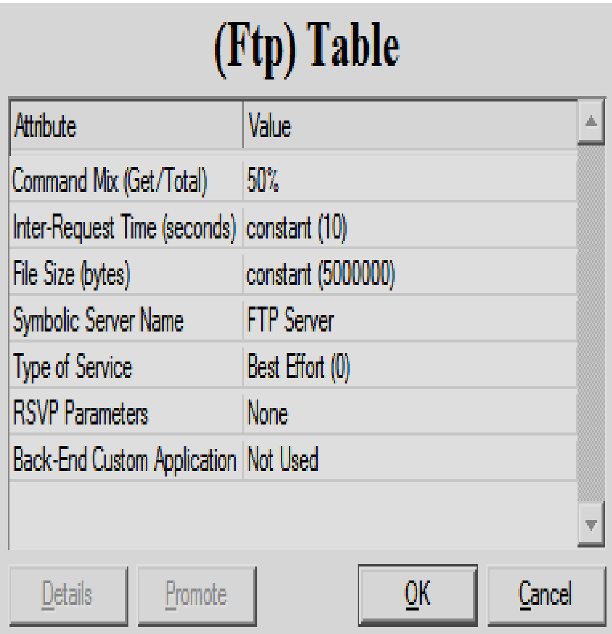


(Http) Table

Attribute	Value
HTTP Specification	HTTP 1.1
Page Interarrival Time (seconds)	exponential (60)
Page Properties	(...)
Server Selection	(...)
RSVP Parameters	None
Type of Service	Excellent Effort (3)

Figure 5. HTTP Application Configured

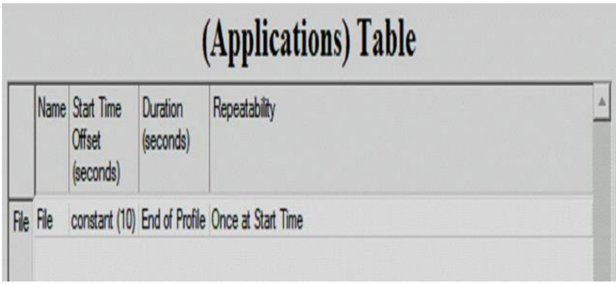
The file transfer protocol (FTP) is configured to supports the heavy load file application up-to 5MB of size at an inter-request time of constant 10. It also supports the best effort file services delivery for meeting the expected quality of service. As shown in the figures 6 and 7 below is the outline of the configuration.



(Ftp) Table

Attribute	Value
Command Mix (Get/Total)	50%
Inter-Request Time (seconds)	constant (10)
File Size (bytes)	constant (5000000)
Symbolic Server Name	FTP Server
Type of Service	Best Effort (0)
RSVP Parameters	None
Back-End Custom Application	Not Used

Figure 6. FTP Application Configured

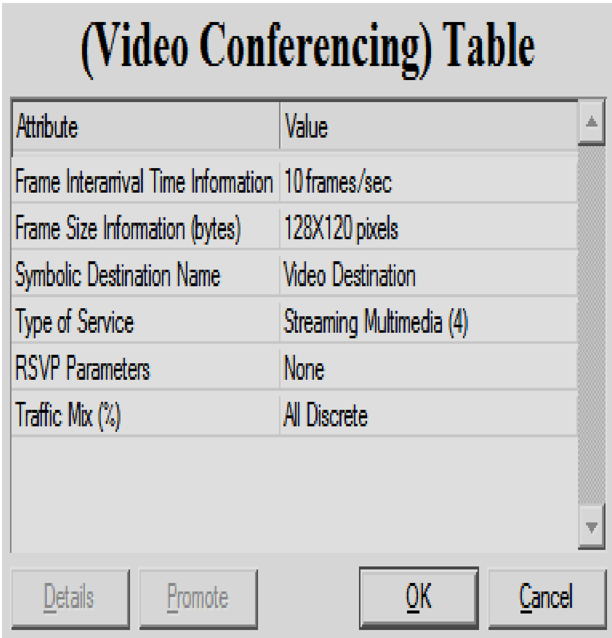


(Applications) Table

	Name	Start Time Offset (seconds)	Duration (seconds)	Repeatability
File	File	constant (10)	End of Profile	Once at Start Time

Figure 7. FTP Configuration Table

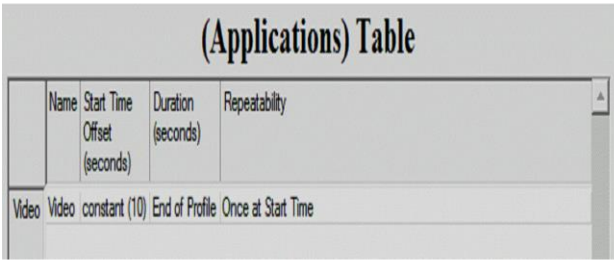
Additionally, video conferencing application is configured as low resolution quality video, with 10 frames interval per seconds and frame size of 128X120 pixels as shown in figures 8 and 9 below. It provides support for streaming multimedia application services.



(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

Figure 8. Video Conferencing Application Configured



(Applications) Table

	Name	Start Time Offset (seconds)	Duration (seconds)	Repeatability
Video	Video	constant (10)	End of Profile	Once at Start Time

Figure 9. Video Conferencing Application Table

The profile configuration for voice application is shown clearly in the figures 10 and 11 below. In the configuration, voice have assigned pulse code modulation (PCM) quality speech and supported the interactive voice services.

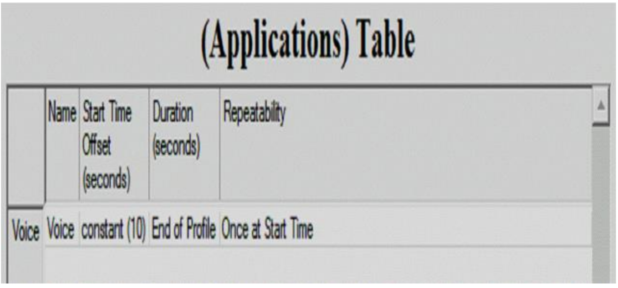


Figure 10. Voice Configuration Table

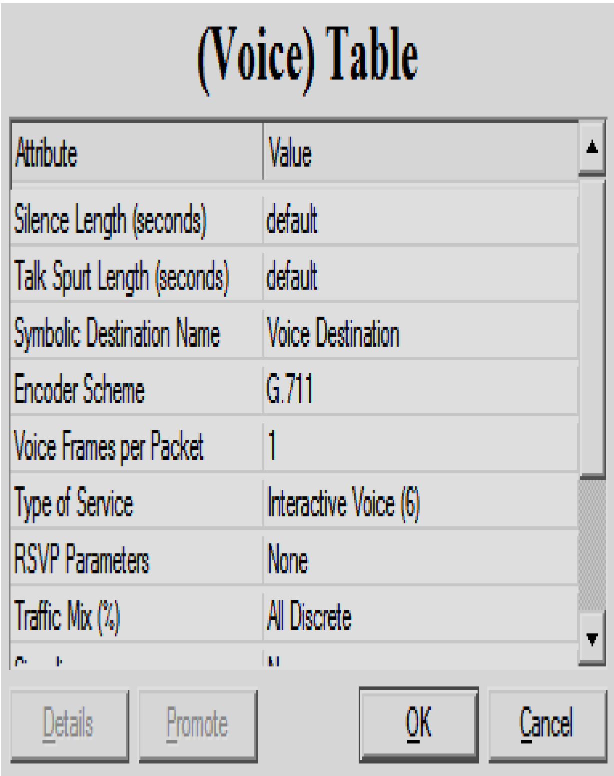


Figure 11. Voice Application Configured

4. SIMULATION RESULTS

Various simulations scenarios are analyzed under the constructed discrete event simulation environment. The graphical scenarios results have been taken and also examined. Moreover, significant performance improvements are recorded.

In terms of throughput, delay and packets loss, our proposed algorithm performs efficiently over the selected traditional scheduling algorithm. And also the available network resources are utilized effectively. In the packet dropped graph shown in the figure 12 below, indicated clearly that the algorithm has the least probability of dropping packets in the network. As represented by the blue line, the number of packets drop in a second is uniform throughout the simulation in comparison with red and green line for the first-in-first-out and priority queue. This gives an outstanding detail about the efficient performance of our proposed scheme during successful packet transmission in a network.

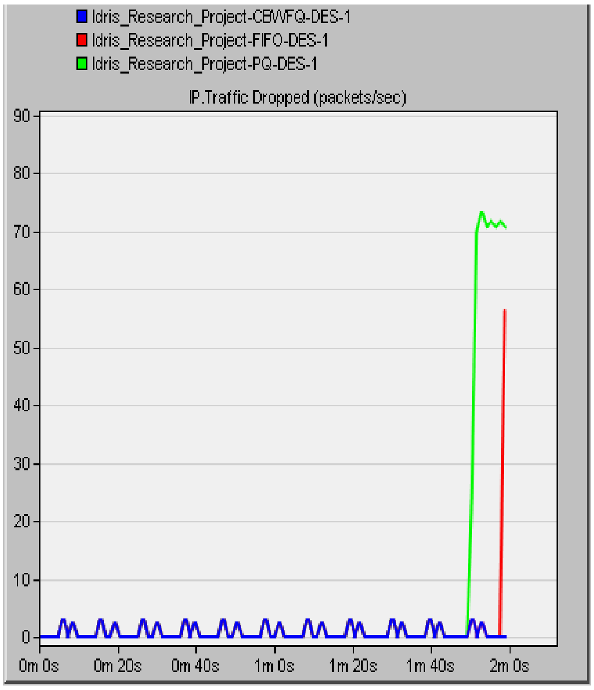


Figure 12. IP Traffic dropped in packet/second

As depicted in the figures 13 and 14 below is the packets end to end delay in second for video and voice traffic. On arrival packet have experienced the maximum queuing delay when encounter a packet receiving service at the head of its queue. From the graphs, CBWFQ packet represented by the blue dotted line has minimal delay compared to PQ and FIFO respectively. Consequently, the algorithm work best in transmitting a packet from source to destination in a network.

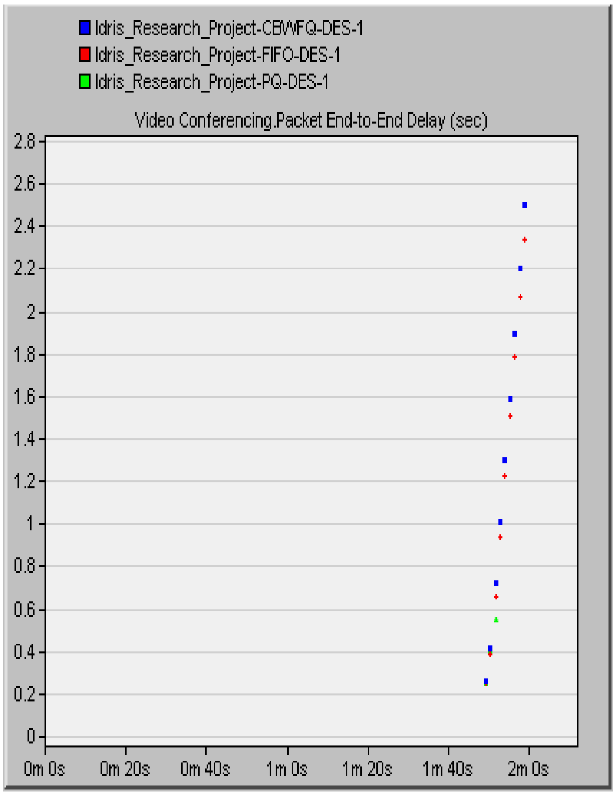


Figure 13. Video Conferencing Packets ETE

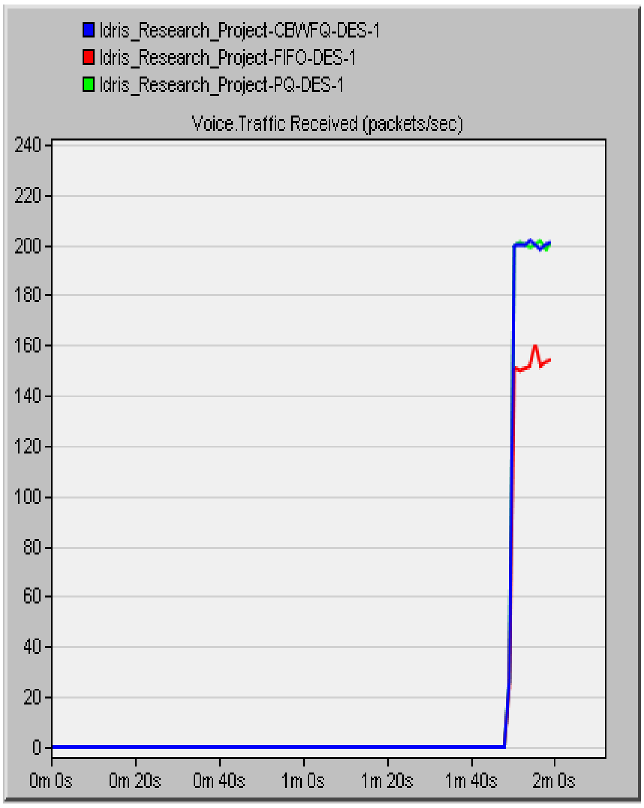


Figure 15. Voice Traffic Received

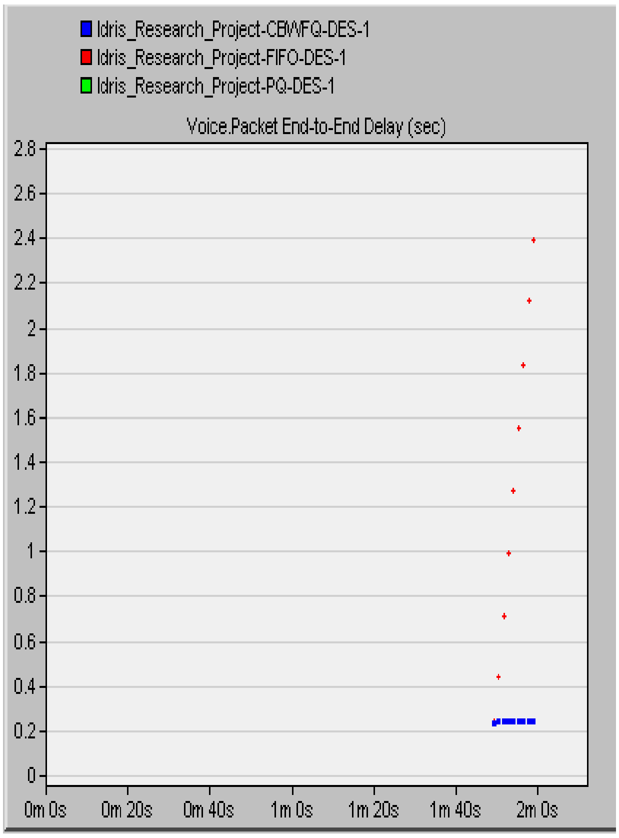


Figure 14. Voice Packets ETE Delay (sec)

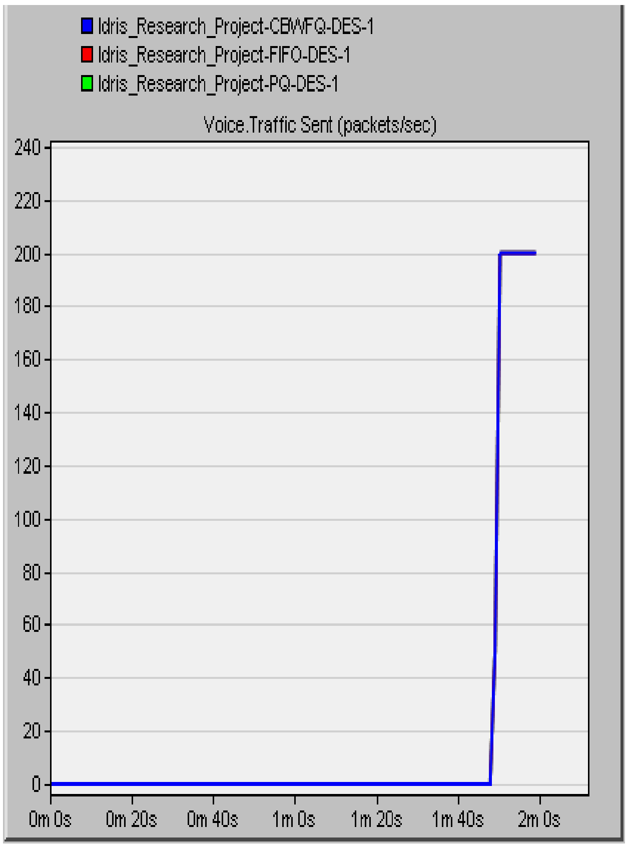


Figure 16. Voice Traffic Sent

4 CONCLUSION

The detailed implementation of the class-based weighted fair queue with the first-in-first-out and priority queue using OPNET simulator is fully outlines. The fundamental use of the packet scheduling algorithm in the transmission of packet and managing of network resources is examines. Moreover, simulations experiments are conducted and also scenarios are generated. Simulations results are studied and analyzed. The effectiveness of the proposed algorithm in terms of packet loss, throughput and bandwidth utilization is clearly illustrated. And also, the optimal performance improvement attained is recorded, that shows the efficiency of the proposed algorithm over the selected traditional scheduling mechanism. The study contributed immensely in benefitting an organization and industries to manage their internet network resources and provides the efficient services required by the users.

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