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ENHANCED LOW LATENCY QUEUING ALGORITHM FOR REAL TIME APPLICATIONS IN WIRELESS NETWORKS

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ABSTRACT

In recent times, the demand for the real time audio and video applications in wireless networks is very high due to widespread use of latest wireless communication technologies. Many of these applications require different Quality of Service (QoS) in terms of delay and throughput in the resource constrained wireless networks. In order to handle the resources effectively and to increase the QoS, proper packet scheduling algorithms need to be developed. Low-latency Queuing (LLQ) is a packet scheduling algorithm which combines Strict Priority Queuing (SPQ) to Class-Based Weighted Fair Queuing (CB-WFQ). LLQ places delay sensitive applications such as voice and video in the SPQ and treat them preferentially over other traffic by allowing the application to be processed and sent first from the SPQ. In this paper, an Enhanced LLQ (ELLQ) is proposed. An additional SPQ is introduced for scheduling the video applications separately along with the dedicated SPQ for voice applications. The performance of the proposed algorithm is compared with other existing algorithms through simulations using the OPNET modeler. Simulation and Statistical results show that the proposed algorithm has given 1.5 times performance improvement in terms of throughput and delay than the existing algorithms for the real time audio and video applications.

Keywords: Low Latency Queuing (LLQ); Quality of Service (QoS); Real time applications; Scheduling algorithms; Wireless networks

1. INTRODUCTION

One of the provocative issues in wireless networks is to provide the QoS due to the limited resources and the nature of time variances of the wireless networks. To utilize the resources efficiently and to increase the QoS for the real time applications, proper packet scheduling algorithms need to be developed. The packet scheduling algorithm determines the order of packet delivery based on the nature of the packet. Hence, the delay sensitive real time applications will be processed faster than the non-real time applications (Annadurai, 2011).

From the application viewpoint, the QoS denotes the application quality perceived by the user, whereas in the network's viewpoint, it is the service quality provided by the network to the applications in terms of the network QoS parameters, such as latency, reliability and throughput (Shaimaa et al., 2011). The QoS factors vary depending on the application. For example, throughput and delay are the vital factors for real time applications, whereas security and availability are very important factors in case of military applications. In case of emergency applications, availability is the key factor.

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In order to provide the QoS guarantees, the packet scheduling algorithm has become one of the most important components. It will monitor the queuing fluctuations in various circumstances and also increase the network's performance. Advancement in the multimedia and Internet applications has necessitated the importance of studying the scheduling algorithms for providing the QoS assurances with respect to delay, jitter, assured rate and fairness among the various sessions (Rukmani & Ganesan, 2013).

The traditional packet scheduling algorithm is First-In-First-Out (FIFO), which places all packets into a single queue and processes them in the same order as they are received. The FIFO is easy to implement, but it cannot differentiate among the different types of traffic. Bursty traffic is related to relatively high bandwidth traffic at inconsistent levels. If bursty traffic comes in, then the whole buffer space will be used in the FIFO. It may cause delays in real time sensitive traffic and also, other flows may not be serviced until the buffer is empty (Tetsuji, 2010). To overcome these limitations and to provide fair sharing of the resources, many other types of scheduling methods, such as Priority Queuing (PQ), Weighted Round Robin (WRR), Weighted Fair Queuing (WFQ), Custom Queuing (CQ) and Class-Based Weighted Fair Queuing (CB-WFQ) are designed. The real time applications are treated preferentially in the priority queuing algorithm. But, when the amount of higher-priority traffic is excessive, the PQ suffers a starvation problem and complete resource malnourishment for the lower-priority traffic (Tetsuji, 2010). In case of WFQ, CQ and CBWFQ, there is no priority servicing for the real time applications.

In order to overcome these problems, Cisco Systems has introduced a Low Latency Queuing (LLQ) algorithm which combines a single strict priority queue with CB-WFQ. The high priority traffic could be placed in the strict priority queue. It permits delay sensitive voice and video traffic to be scheduled first before the packets in the other queues. The key difference between the LLQ and the PQ is that the LLQ strict-priority queue will not starve the low priority queues. It is controlled by the bandwidth policer, either by the bandwidth or a percentage of the bandwidth (Brunonas et al., 2006; Chuck, 2001). Other Network corporates, like FatPipe Networks, Juniper Networks, CheckPoint, and Palo Alto Networks, are also sensitized to assigning high priority to real time applications.

In this paper, as described in Section I, an enhanced packet scheduling algorithm is proposed, which extends the structure of the LLQ algorithm to increase the QoS for video applications. Section II illustrates related work. The proposed algorithm is discussed in Section III. Simulation results are presented in Section IV. Finally, the conclusion and future work is summarized in Section V.

2. RELATED WORK

A huge amount of bandwidth is required for teleconferencing and video on demand services in the Internet. Bandwidth provision in large quantities is not an easy task in Internet services due to persistent changing nature of the Internet. With the help of appropriate buffer handling mechanisms, the bandwidth can be managed efficiently (Farzad et al., 2008). Hence, the multimedia applications can be delivered with the required QoS. An urgency-based packet scheduling is developed to deliver delay sensitive data in mobile networks effectively (Hyunchul et al., 2011). Packet urgency, route urgency and node urgency are defined, based on the end-to-end delay requirements and the number of hops over a route. The urgency metrics determined the order of packet scheduling for dropping the packets.

A model has been developed to give a higher priority to voice and video traffic which is the most sensitive (Jesus et al., 2006). The model monitors all incoming traffic and categorizes it based on the level of their sensitivity. Then, it assigns the highest priority to voice and video traffic and a lower priority to other traffic which are delay tolerant. This sequence occurs so that high priority traffic can be delivered to the destination directly without considering a congestion avoidance technique. A novel Low Latency and Efficient Packet Scheduling (LLEPS) algorithm is developed to ensure low latency for real time audio and video streaming applications (Eric et al., 2006). The behavior of queues and their traffic is monitored to address the buffer under-run problem.

Shaimaa et al. (2011) have demonstrated that the combination of Class-Based Weighted Fair Queuing and Low Latency Queuing (CB-WFQ-LLQ) improved the performance of multimedia applications. This was verified with the help of experimental results done in OPNET IT Guru as below:

a) Without using any QoS technique, the first experiment was conducted on a First Come First Serve (FIFO) basis. Non-real time applications, such as Hyper Text Transfer Protocol (HTTP), File Transfer Protocol (FTP) etc. have more privileges and occupy more buffer spaces and introduce negative effects on the multimedia applications, i.e. voice and video, since a long loading time time results in delay and the system starts to drop packets.
b) The second experiment was conducted using CB-WFQ-LLQ at routers for video traffic. The delay sensitive applications are provided with strict priority. The results indicate that the performance of the video traffic has improved, but it was affecting other traffic, including voice.
c) The third experiment prioritizes voice and video traffic. This experiment improved the overall performance of the network. To attain even better quality for multimedia applications the QoS has to be extended to Layer 2.

A flexible Earliest Deadline First (EDF) scheduling is proposed to assign priority for multimedia packets in mobile ad hoc networks (Youssef et al., 2008). The existing EDF confers poor results in overloaded conditions and a well-known problem called the domino effect may occur. The proposed model allocates priority for different classes of traffic based on the sigmoid priority function. Simulations are done in the province of system overload and the outcomes prove that the FEDF scheme performs better than the EDF scheduling in the proposed multiclass model.

3. PROPOSED WORK

The LLQ is essentially a CB-WFQ combined with a SPQ. Traffic assigned to the SPQ is completely serviced before all other CB-WFQ queues are serviced. The existing LLQ algorithm gives strict priority mostly to voice applications only. Advancements in the field of Telesurgery, Video Conferencing and E-Learning applications had increased the demand for High Quality Video services in the recent years. Table 1 shows the traffic characteristics for video and voice applications (Wendell & Michael, 2004).

Table 1 Traffic characteristics for different applications

Application	Bandwidth	Delay	Jitter	Loss
Voice	Low	Low	Low	Low
Interactive Video	High	Low	Low	Low
1-Way Video	High	Medium/High	Low	Low

Interactive Video applications, which deliver both Video and Voice, are very similar to the Voice Applications in terms of the characteristics as depicted in the Table 1. The demand for the streaming videos is increasing these days due to its wide usage in various fields, such as E-Learning and Video on Demand. But the streaming video applications are little bit delay and buffer tolerant compared to the Interactive video applications. In addition to the voice traffic, strict priority status can be given to the video traffic to satisfy the QoS requirements in interactive video applications and to provide the service guarantee in streaming video applications.

In the LLQ, it is possible to include various types of real time traffic into the single SPQ. But, the expected QoS level cannot be guaranteed, if sensitive audio and video packets are processed in the single SPQ.

The drawbacks in the existing LLQ are:

a) The expected QoS level cannot be guaranteed, if sensitive audio and video packets are processed in the single priority queue due to resource sharing between many applications.
b) If a bursty video packet comes, the voice traffic also may not be delivered successfully (Brunonas et al., 2006). The reason is that the behavior of the voice traffic is controllable whereas the video traffic is uncontrollable.
c) Also, to avoid jitter, voice traffic requires a non-variable delay, which is the most important for voice applications. However, video traffic could introduce a variation in the delay, thereby spoiling the steadiness of the delay required for successful voice traffic transmission.
d) There is no distinctive consideration for video applications, which also require more throughputs and less delay.

In order to overcome these problems, an additional SPQ is introduced along with the existing SPQ in the proposed system as illustrated in Figure 1. The existing SPQ, which is primarily dedicated for delay sensitive voice traffic in the existing algorithm is re-named as Primary Strict Priority Queue (PSPQ) and a new queue is added, which is named the Secondary Strict Priority Queue (SSPQ). This SSPQ will be exclusively used for video traffic. All other classes of traffic are processed using the class-based weighted fair queuing algorithm.

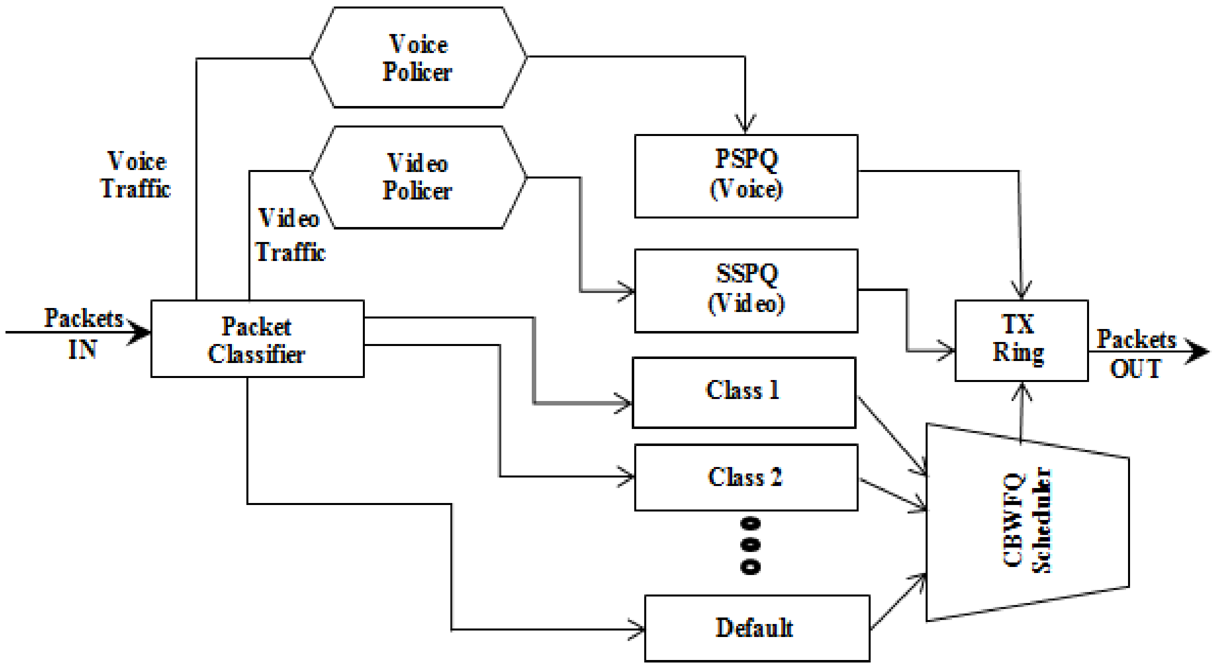

Figure 1 Enhanced Low Latency Queuing algorithm (ELLQ)

LLQ is flexible to add as many numbers of SPQ, but by adding higher numbers the SPQs will end up in starvation for low priority applications like the traditional PQ. In our proposed work, we have introduced only one additional SPQ that is dedicated for video applications. The reason is strict priority status can be set to real time applications only as per industry recommendations. In general, applications consisting of voice and video are only to be considered as real time applications. Inside the SPQ, the packets are processed in First in First out (FIFO) order. When the TX Ring (Hardware Queue) has free space, voice packets will be scheduled from PSPQ first and then the video packets will be scheduled from the SSPQ. Inside the SPQ, the packets are processed in First in First out (FIFO) order. When both queues are empty packets from other queues will get an opportunity to be processed based on the CB-WFQ algorithm as given in the pseudo code below

WHILE** TX Ring has free space **Do
IF** PSPQ is not empty **THEN
Voice packets from PSPQ are placed into TX Ring
ELSE IF** SSPQ is not empty **THEN
Video packets from SSPQ are placed into TX Ring
ELSE
Packets from other classes are placed into TX Ring using CBWFQ
ENDIF

ENDWHILE

4. RESULTS AND DISCUSSION

Our network model has been created using 30 mobile nodes, 6 ethernet routers, 2 ethernet switches and 2 CISCO7200 gateway routers in a 10×10 Km area using an OPNET Modeler (Version 14.5) (Adarshpal, 2013), as shown in Figure 2. The mobile nodes will be moving based on the predefined trajectory.

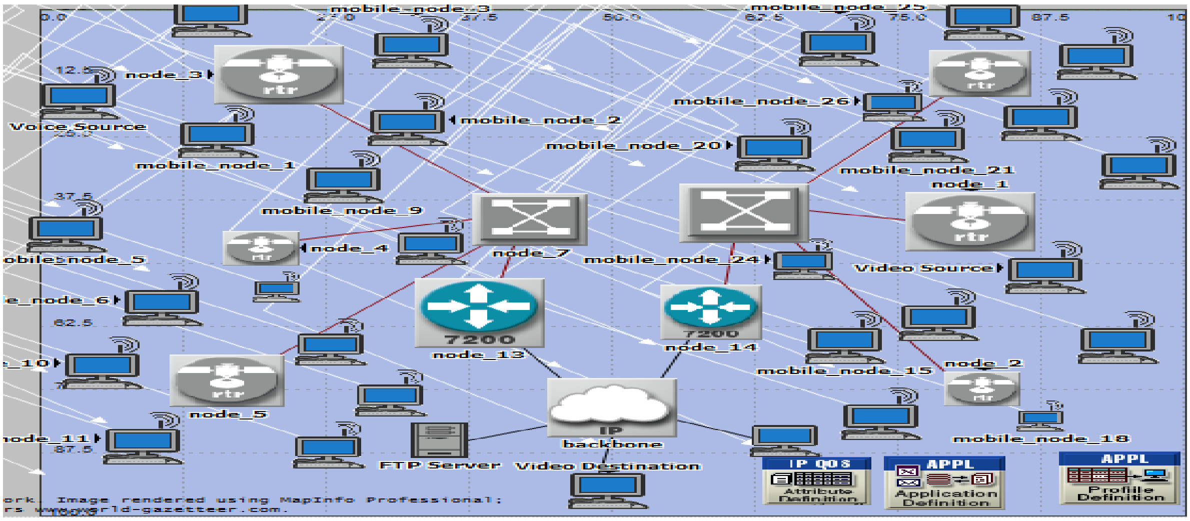

Figure 2 Network model in an OPNET modeler

Input traffic models for voice and video applications are created using application and profile configurations available in OPNET. In the application definition, Type of Service (TOS) is used to represent voice and video traffic in interactive voice, streaming and interactive video. The corresponding DSCP values for the created input traffic models are also assigned in the application definition. Then, the input traffic models will be assigned to the mobile nodes with the help of application profiles.

Six scenarios have been designed to evaluate the performance of the ELLQ algorithm along with other algorithms. The performance of the ELLQ algorithm is analysed by comparing it with other algorithms in terms of throughput and delay. Each factor is discussed fully in the following sections. To better understand the performance of the proposed system, statistical results obtained through simulations are also shown in Table 2.

Table 2 Simulation results statistics

Global Statistics	FIFO	PQ	MWRR	WFQ	LLQ	ELLQ
Voice Traffic Received (packets/sec)	47.62	47.86	46.90	48.13	47.62	48.33
Voice Jitter (jitter/sec)	0.0001236	0.0000088	0.0001384	0.0000088	0.0001236	0.0000396
Video Conferencing Traffic Received (packets/sec)	19.753	19.887	19.823	19.783	19.753	22.390
Video Conferencing Packet End-to-End Delay (delay/sec)	0.040370	0.040567	0.040176	0.040567	0.040370	0.044458
Wireless LAN Delay (delay/sec)	0.029548	0.029527	0.029440	0.029527	0.029548	0.028523
Wireless LAN Throughput (bits/sec)	3,592,922	3,593,934	3,593,675	3,593,934	3,592,922	3,639,722

4.1. Voice Traffic Received

It is observed from the graphical results shown in Figure 3 that the average voice traffic received in the ELLQ algorithm gives better performance when compared to all other algorithms. The dedicated PSPQ for the voice applications in the ELLQ improved the overall traffic received, compared to all other algorithms as shown in Table 2. Increase in the voice traffic received is very important in determining the performance of our proposed work. The dedicated PSPQ gives a notable increase in the voice traffic received, which helps in providing a good quality voice and henceforth increases the total amount of voice traffic to be received on the receiver side.

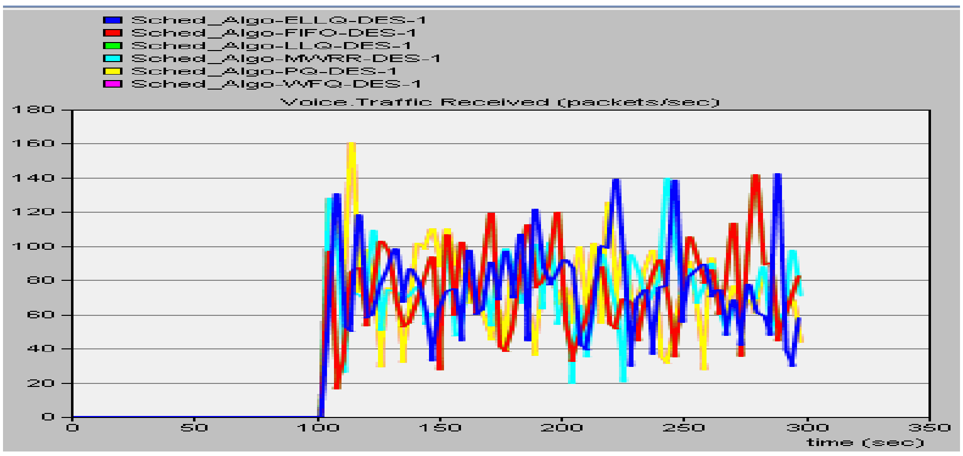

Figure 3 Voice traffic received (packets/sec)

4.2. Voice Traffic Jitter

Voice jitter is shown in Figure 4. Graphical results show that PQ, WFQ and ELLQ give better performance when compared to other algorithms. The numerical results in Table 2 prove that

ELLQ gives less jitter than LLQ. The dedicated strict priority queue, i.e. PSPQ in the ELLQ improved the average jitter value in the ELLQ algorithm. Due to the decrease in the value of jitter, there is considerable improvement in the voice quality to be received on the receiver side.

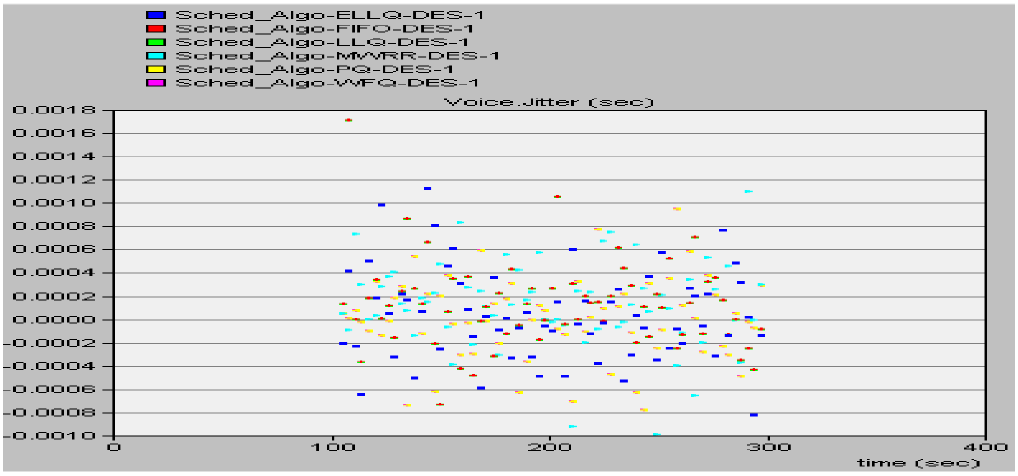

Figure 4 Voice traffic jitter (jitter/sec)

4.3. Video Traffic Received

Figure 5 shows the performance comparison of the ELLQ algorithm with existing algorithms in terms of video traffic received. It is observed that the ELLQ algorithm shows good performance when compared to all other algorithms as shown in Table 2. The dedicated secondary strict priority queue, i.e SSPQ for the video traffic in the ELLQ improved the overall traffic received better than other algorithms. Increase in the video traffic received is very important in determining the performance of our proposed work for video applications. The newly added SSPQ gives a notable increase in the video traffic received, which helps in providing a good quality video and also increases the total amount of video traffic to be received.

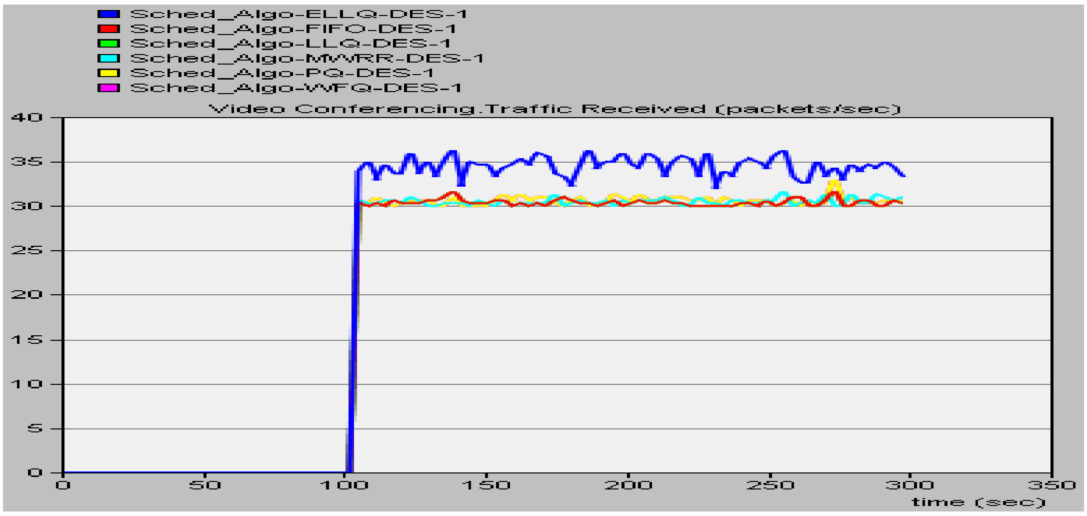

Figure 5 Video traffic received (packets/sec)

4.4. Video Traffic End-to-End Delay

From the simulation results shown in Figure 6, it was observed that the end-to-end delay in the ELLQ was higher than in other algorithms. The slight variation in the delay might have occurred for the reason that the video packets in the SSPQ are scheduled after scheduling the voice packets in the PSPQ.

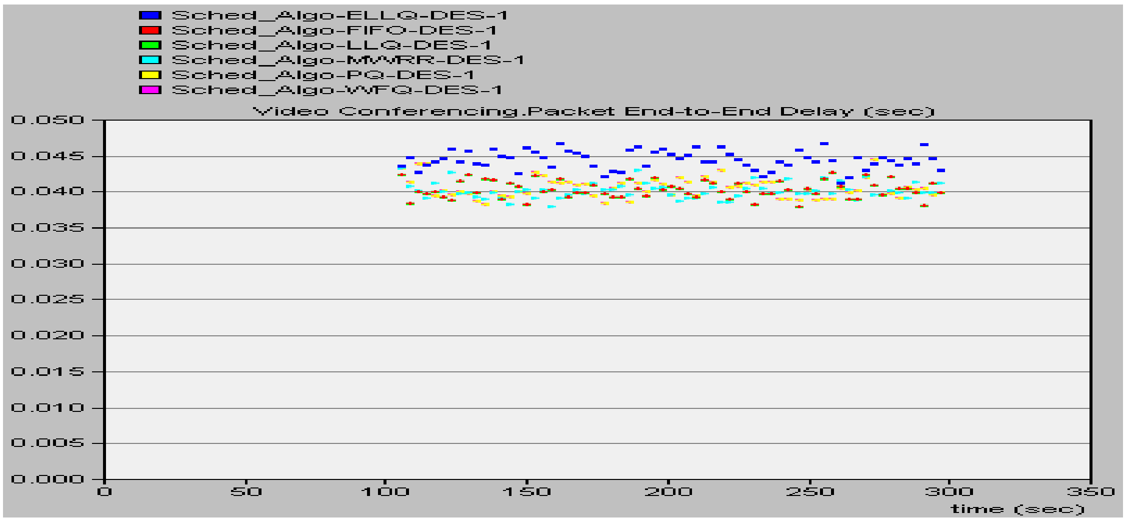

Figure 6 Video Traffic End-to-End Delay (delay/sec)

Dynamic scheduling between the SPQ's can be considered to reduce the video traffic delay. Based on the nature of the application, it could be possible to schedule the video packets from the SSPQ before scheduling the packets from the PSPQ.

4.5. WLAN Delay

By looking at the graphical results shown in Figure 7, the overall WLAN delay is very less in the ELLQ algorithm. Both voice and video traffic are serviced separately in two different queues, thereby it reduced the overall network delay as shown in Table 2.

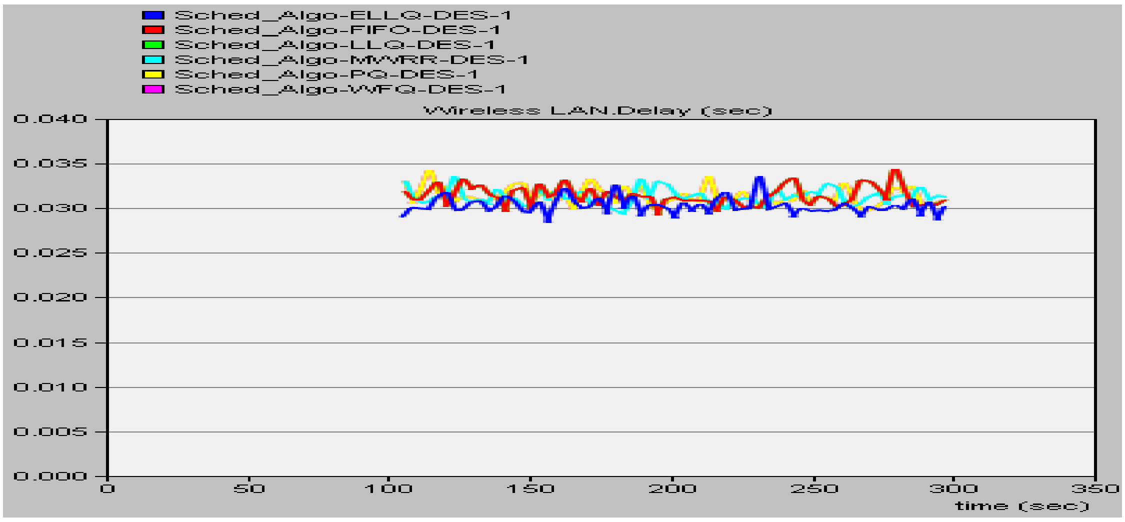

Figure 7 Wireless LAN Delay (delay/sec)

4.6. WLAN Throughput

The graphical results shown in Figure 8 gives the WLAN throughput obtained in the simulation. Throughput is the most important performance measurement to determine the performance of the proposed system. It is very difficult to get equal throughput in any network. But, the objective of our proposed system is to increase the throughput for multimedia applications. The voice and video traffic are serviced separately in two different queues, thereby the proposed system slightly increased the overall network throughput as shown in Table 2.

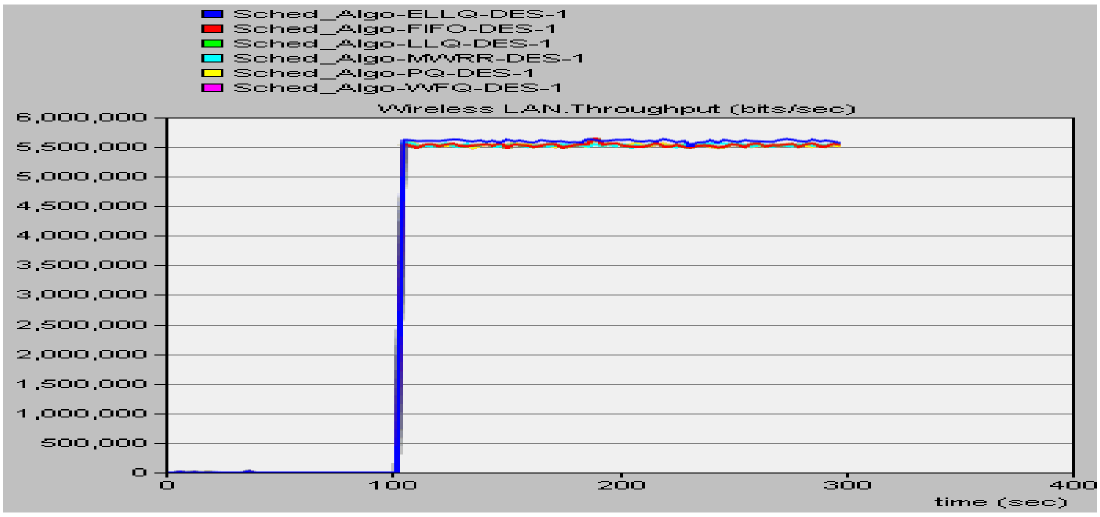

Figure 8 Wireless LAN Throughput (bits/sec)

5. CONCLUSION AND FUTURE WORK

In this paper, we proposed an enhanced LLQ algorithm that effectively supports real time applications over wireless networks. The proposed algorithm uses two strict priority queues, namely Primary Strict Priority Queue (PSPQ) for voice and Secondary Strict Priority Queue (SSPQ) for video traffic. Through the simulation and statistical results, it is shown that the proposed algorithm guarantees maximum throughput and satisfactory end-to-end delay towards real time applications when compared to other existing algorithms. Also, it is observed that the end-to-end delay for video traffic is slightly higher in the proposed algorithm.

As a future work, it has been planned to develop some appropriate strategies to overcome this issue for video traffic as an extension to the proposed algorithm. It could be possible to schedule the video packets from the SSPQ before scheduling the voice packets from the PSPQ by considering the nature of the application. And, an appropriate method also can be developed to decide the selection of the strict priority queues for scheduling the packets dynamically.

6. ACKNOWLEDGEMENT

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