Chapter 5

IMPLEMENTATION AND SIMULATION

5.1 NETWORK CONFIGURATION

In this simulation model, we have used OPNET IT Guru to build a small IP network and apply QoS policies, to analyze the performance of the network in terms of packet loss and delay for different kinds of video streaming applications.The network is composed of four pairs of video clients. Each pair uses a distinct ToS (Type of Service) for data transfer.Two different LAN networks were connected, one consisting of different video streaming clients and the other consisting of the corresponding video servers. Router A was connected to four clients through the switch. There are four servers connected to router B again through another switch and clients.Figure 5.1.

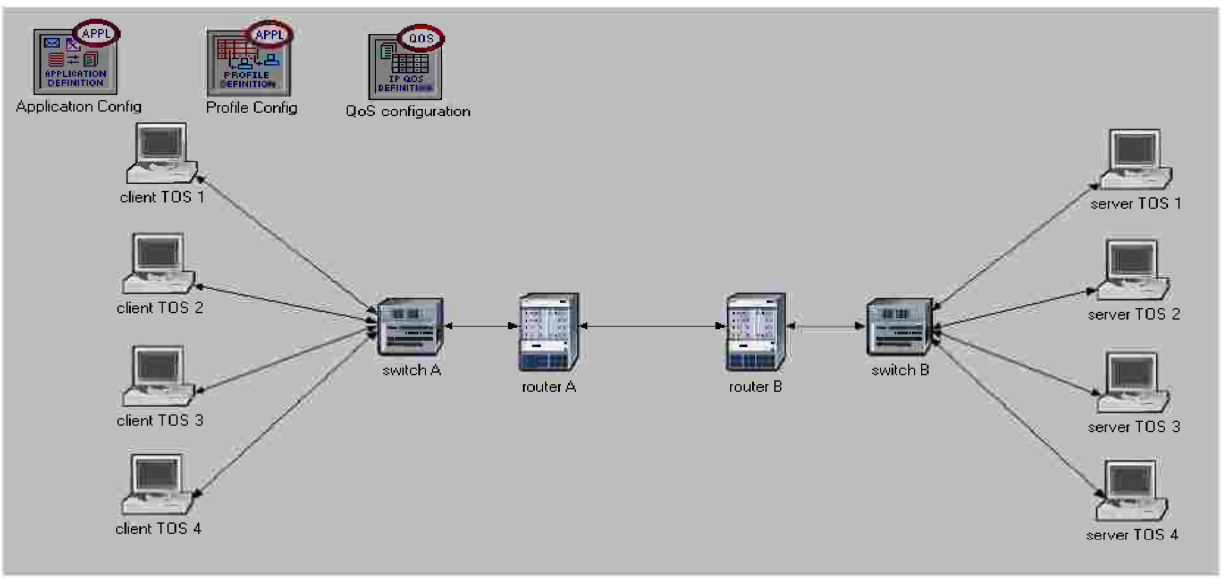

Figure 5.1 Network Configuration.

<u>5.1.1 Application Configuration Object</u>

Application configuration is used to specify applications that will be used to configure user profiles. Even though there are different possible applications which can be configured, like database access, email, file transfer, file print, telnet session and video conferencing.I have chosen different types of video conferencing applications for individual clients.
Then I have customized the application requirements by setting the parameters for the selected application. Application configuration object is an object used to define and configure all Applications in the network according to the user requirements which in this case are four video conferences.

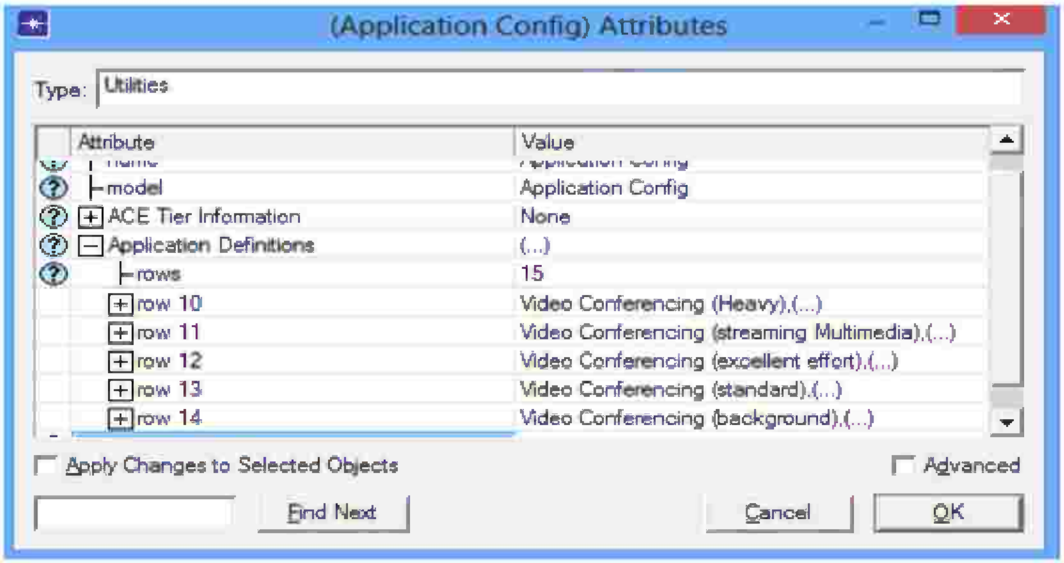

Figure 5.2 Application configuration attributes.

Table 5.1 Application configuration.

Attribute	Value
Frame Interval Time Information	30 frames/sec
Incoming Stream Frame Size (bytes)	constant (2500)
Outgoing Stream Frame Size (bytes)	constant (2500)
Symbolic Destination Name	Video Destination
Type of Service	Streaming Multimedia (4)
RSVP Parameters	None
Traffic Mix (%)	All Discrete

Table 5.2 Type of service.

<table>
<tr><td rowspan="9">Type of Service</td><td>ToS Value</td><td>ToS Type</td></tr>
<tr><td>0</td><td>Best Effort</td></tr>
<tr><td>1</td><td>Background</td></tr>
<tr><td>2</td><td>Standard</td></tr>
<tr><td>3</td><td>Excellent Effort</td></tr>
<tr><td>4</td><td>Streaming Multimedia</td></tr>
<tr><td>5</td><td>Interactive Multimedia</td></tr>
<tr><td>6</td><td>Interactive Voice</td></tr>
<tr><td>7</td><td>Reserved</td></tr>
</table>

5.1.2 Profile Configuration Object

Profile configuration object is an object that can be used to create users profiles. Profile can contains one or more applications and each application can be configured by the starting time and ending time. In this thesis, there are four profiles: Background traffic, Standard traffic, Excellent Effort traffic, and Streaming traffic.

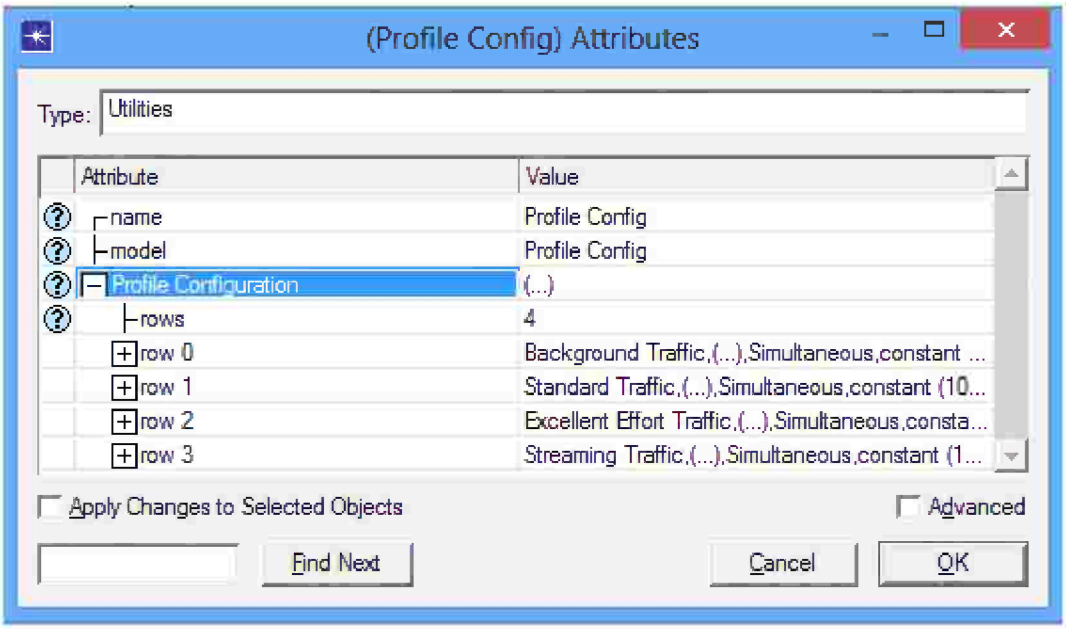

Figure 5.3 Profile configuration attributes.

FIFO queuing can be enabled on each interface in "advanced" routers. Queuing profile and queuing processing mechanism are set in attribute "QoS info" in "IP Address Information" compound attribute. It defines the number of queues, the classification scheme and the QoS configuration object.

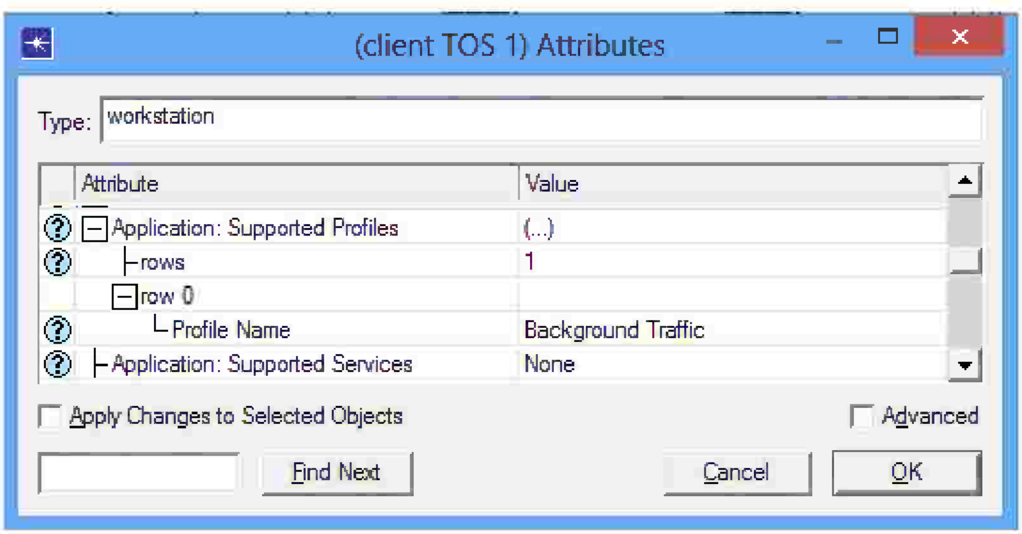

Figure 5.4 Client attributes.

5.1.3 QoS Attribute node

QoS attribute node is a mean of attribute configuration details that assess protocols at the IP layer. It deals with the four queuing profiles: FIFO, PQ, CQ, and WFQ. Also the RED algorithm can be applied on the previous four profiles. Through the configuration RED min =100, and RED max = 200, Exponential Weight Factor =9. ToS4 has the highest priority, and ToS1 has the lowest priority.

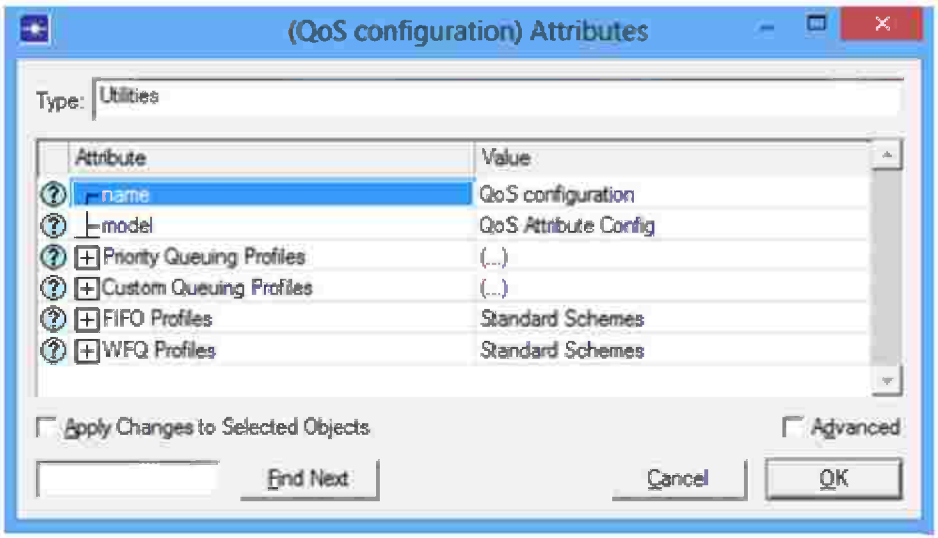

Figure 5.5 QoS configuration attributes.

For Discrete Event Simulation (DES), those parameters which need to be verified are to be selected, like IP, IP interface Video called party, video calling party, video conferencing., end to end packet loss, delay, jitter etc. These settings are done by choosing the respective parameters under global and node statistics of DES parameter settings. Now the simulation engine is run and the different parameters under observation are noted.

5.1.3.1 End-to-End Delay

When the packet transmitted via a network from source to destination then end-to-end delay time has been considered. When it takes too much time to arrive the packet to the receiver, it causing delays in the whole process and therefore has a critical effect on performance of a communication network. Networks with large values of end-to-end delay, the packet can be effectively destroyed. Packet losses due to large end-to-end delay will have impact on the quality of both audio and video traffic on the receiver [1].

5.2 Simulation

5.2.1 FIFO (First in-First out) Queuing

FIFO queuing is the most basic queue scheduling discipline. In FIFO queuing, all packets are treated equally by placing them into a single queue, and then servicing them in the same order that they were placed into the queue. In this model, Maximum queue size =500.

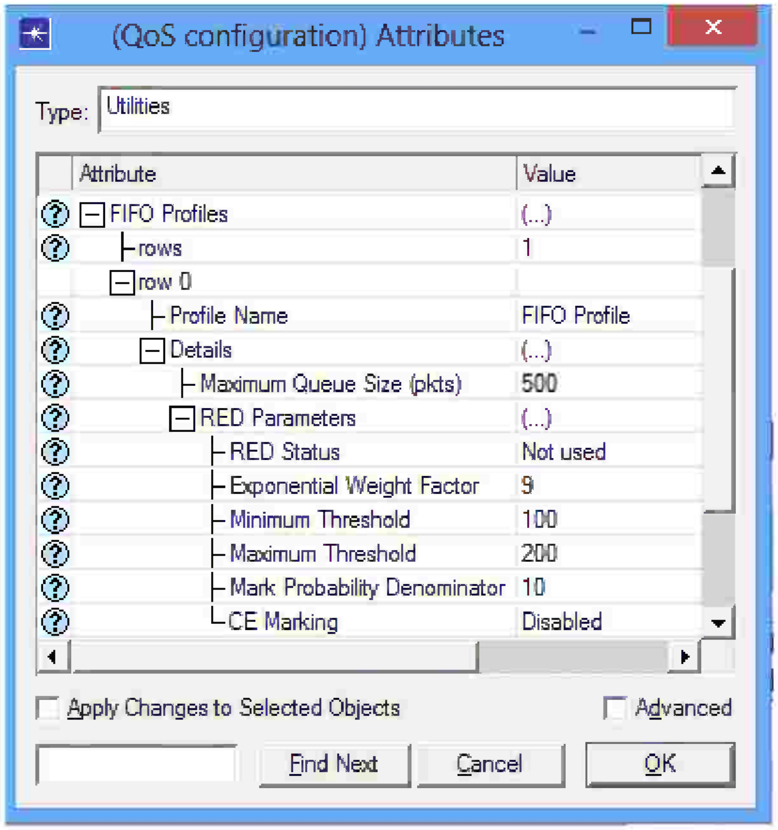

Figure 5.6FIFO configuration.

5.2.2 PQ (Priority Queuing)

Priority queuing (PQ) enables network administrators to prioritize traffic based on specific criteria. This criterion might include protocol or sub-protocol types, source interface, packet size, fragments, or any parameter identifiable through a standard or extended access list. Cisco router offers four different priority queues. Priority queuing (PQ) enables network administrators to prioritize traffic based on specific criteria. This criterion might include protocol or sub-protocol types, source interface, packet size, fragments, or any parameter identifiable through a standard or extended access list. In this example, priority is based on type of service (ToS). Queue 4 sends packets as long it is not empty. Queue 3 sends packets when queue 4 is empty. Queue 2 sends packets when queue 3 and 4 are empty. Queue 1 sends packets when all the other queues are empty.

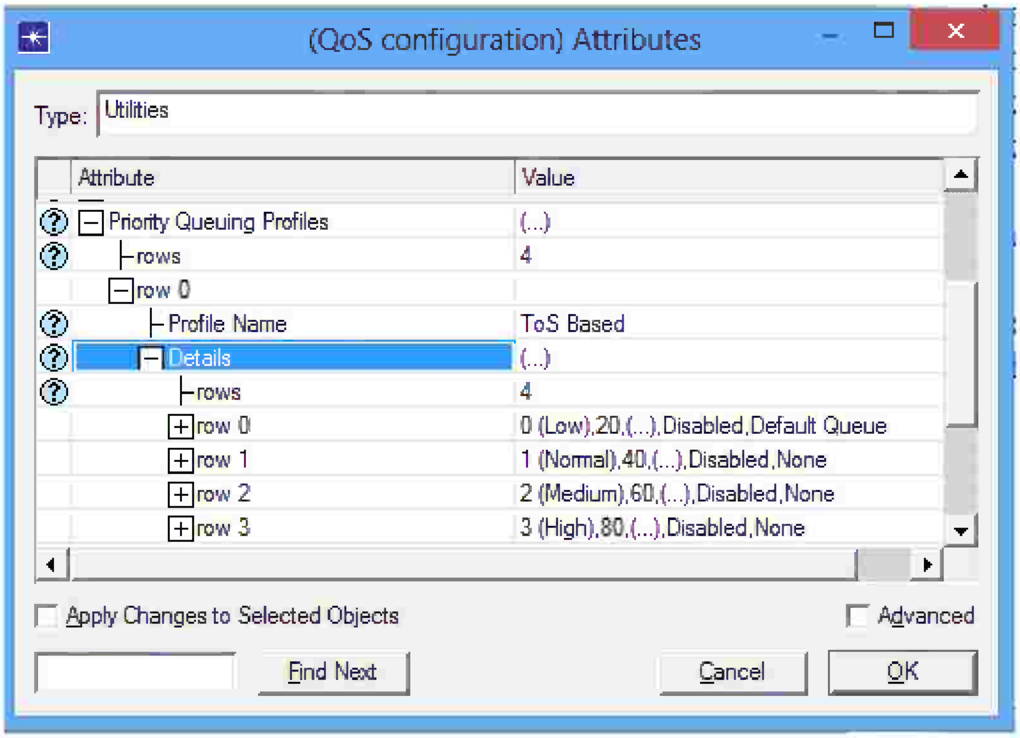

Figure 5.7 Priority Queuing configuration.

5.2.3 CQ (Custom Queuing)

Custom queuing differs from PQ in such a way that CQ is not bound for assigning priority. CQ provides minimum bandwidth requirement for different applications in a network. CQ permits to make 16 custom queues and these queues examines in round robin method. CQ first sends out packet from first queue and then other packet from second queue and then next from third queue. Custom queuing is beneficial in this way that it avoids starvation. Traffic is sent from each queue in a round-robin fashion. The network is composed of four pairs of video clients. Each pair uses a distinct ToS (Type of Service) for data transfer. Routers support multiple queues for each type of service. Queue 4 receives ToS 4 traffic, queue 3 receives ToS 3 traffic, queue 2 receives ToS 2 traffic, queue 1 receives ToS 1 traffic. Queues are serviced using "Custom Queuing" mechanism. Traffic is queued in "router A". In this example, Custom Queuing mechanism differentiates traffic between queues based on the type of service (ToS).

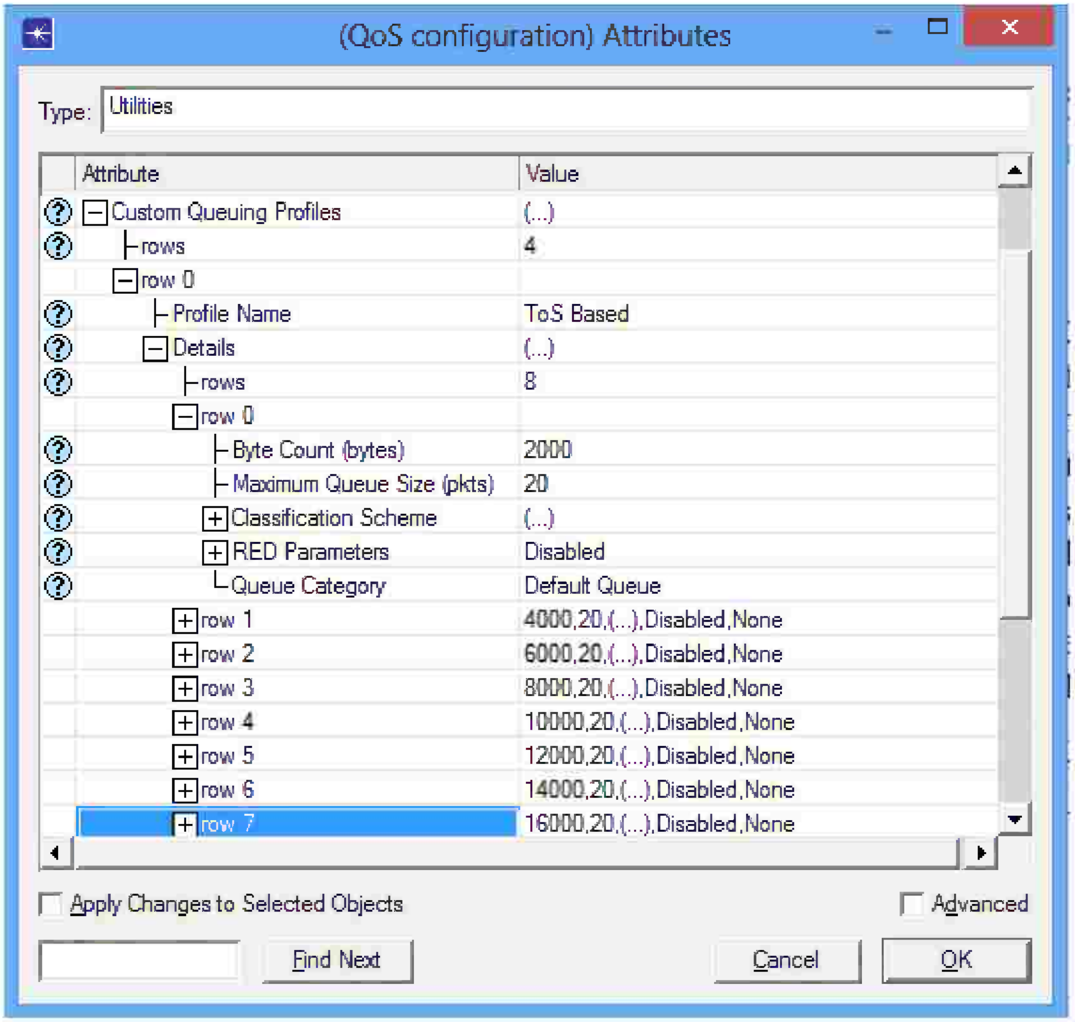

Figure 5.8 Custom queuing configuration.

Table 5.3 CQ configuration.

Decimal bits	ToS	Byte Count
0	best Effort	2000
1	Background	4000
2	Standard	6000
3	Excellent Effort	8000
4	Streaming Multimedia	10000
5	Interactive Multimedia	12000
6	Interactive Voice	14000
7	Reserved	16000

5.2.4 WFQ (Weighted Fair Queuing)

5.2.4.1 Type of service

WFQ queuing can be enabled on each interface in "advanced" routers. Queuing profiles and queuing processing mechanism are set in attribute "QoS info" in "IP Address Information" compound attribute. Queuing profiles define the number of queues and the classification scheme. Queuing profiles are defined in the QoS configuration object. This object is found in "utilities" palette.

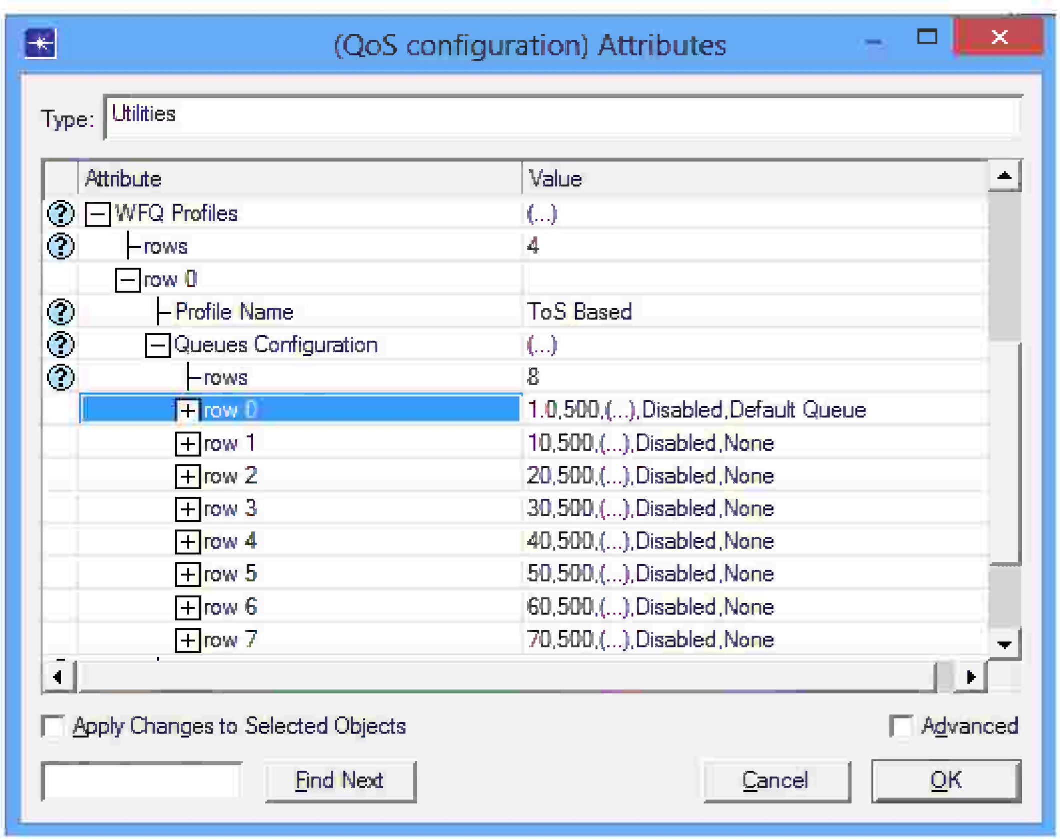

Figure 5.9Weighted fair queuing configuration.

Table 5.4 WFQ configuration.

Decimal bits	ToS	Weight	Max Queue Size (Pkts)
0	best Effort	1	500
1	Background	10	500
2	Standard	20	500
3	Excellent Effort	30	500
4	Streaming Multimedia	40	500
5	Interactive Multimedia	50	500
6	Interactive Voice	60	500
7	Reserved	70	500

5.2.4.2 DiffServ Code Point (DSCP)

DiffServ is a QoS support technology, where network resources are reserved for classes of services. According to the concept of Differentiated Services, traffic evaluation and marking are realized at the network edges. The incoming traffic is sorted into these traffic classes immediately at the edges of the DiffServ domain and the corresponding DSCP is assigned to the packets. In general, packet classification is based on TCP/UDP port numbers and network addresses, which are usually able to identify exact network services, so that different classes can be defined for real-time, business and best-effort data. QoS support in the core network is then based on the DSCP assigned to the packet, which is much faster than analyzing the whole packet header in all core-routers. The DiffServ technology is stateless and it is relatively easy to manage.Opnet Modeler offers sophisticated support to simulate the behavior of Differentiated Services.

Table 5.5 PHB configuration.

PHB	Low Drop	Medium Drop	High Drop	Weight
Background	AF11	AF12	AF13	5
Standard	AF21	AF22	AF23	10
Excellent Effort	AF31	AF32	AF33	15
Streaming Multimedia	AF41	AF42	AF43	25

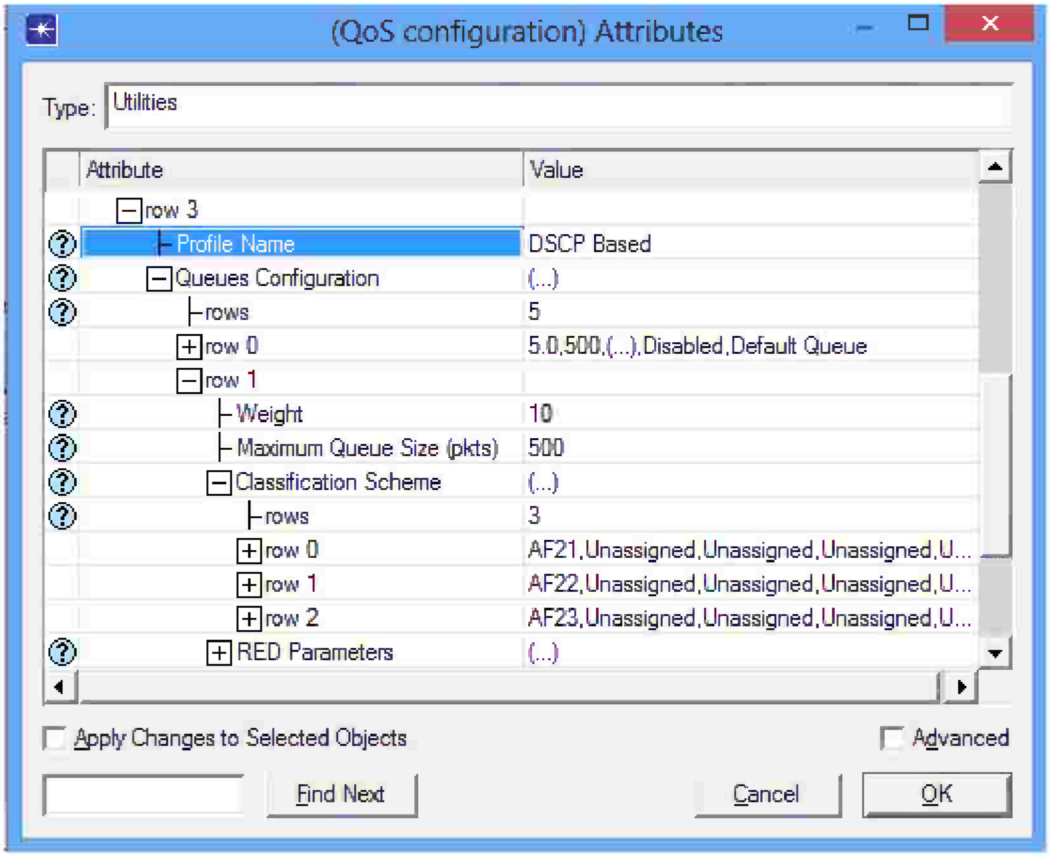

Figure 5.10 DSCP configuration.

5.3 Results

5.3.1Influences of RED algorithm on FIFO

5.3.1.1 FIFO First Input First Output Delay:

The application response time can be seen to reach a threshold because packets that arrive on a full queue always get dropped. Note that the maximum delay that an arriving packet observes is the delay encountered as a result of servicing all the packets ahead of it in an almost full queue.

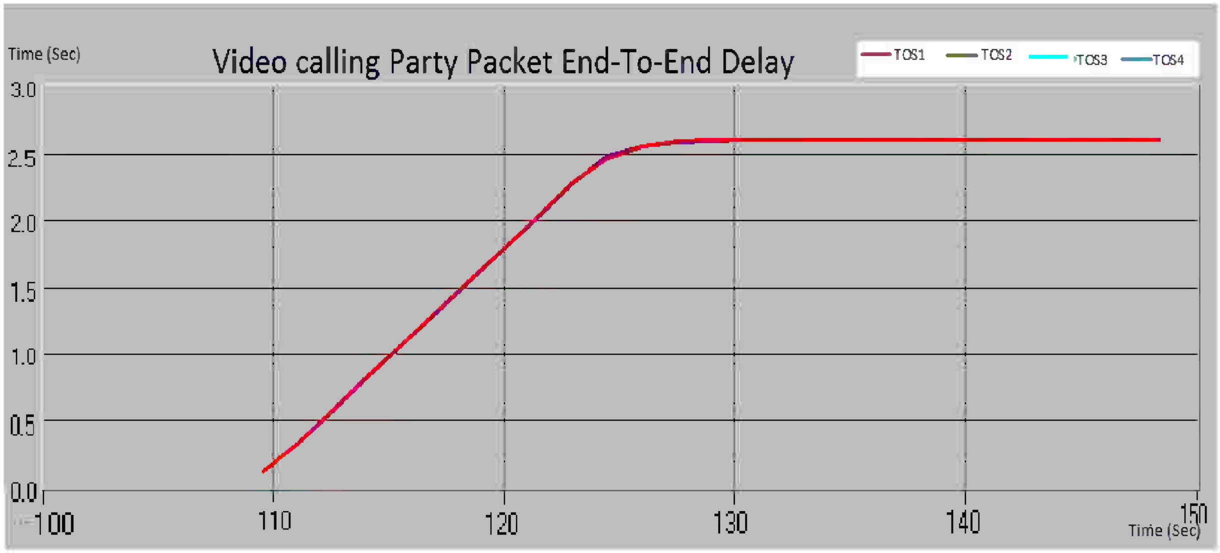

Figure 5.11Delay in FIFO without using the RED algorithm.

Figure 5.11 shows the delay for FIFO profile without using RED algorithm. There are four graphs in the chart. The red graph shows the delay for TOS1, the green one deals with TOS2, the aquamarinegraph shows the delay for TOS3, and the blue graph shows the delay for TOS4. The delay rose gradually for all TOS until the queue is full, then the delay stabilized.

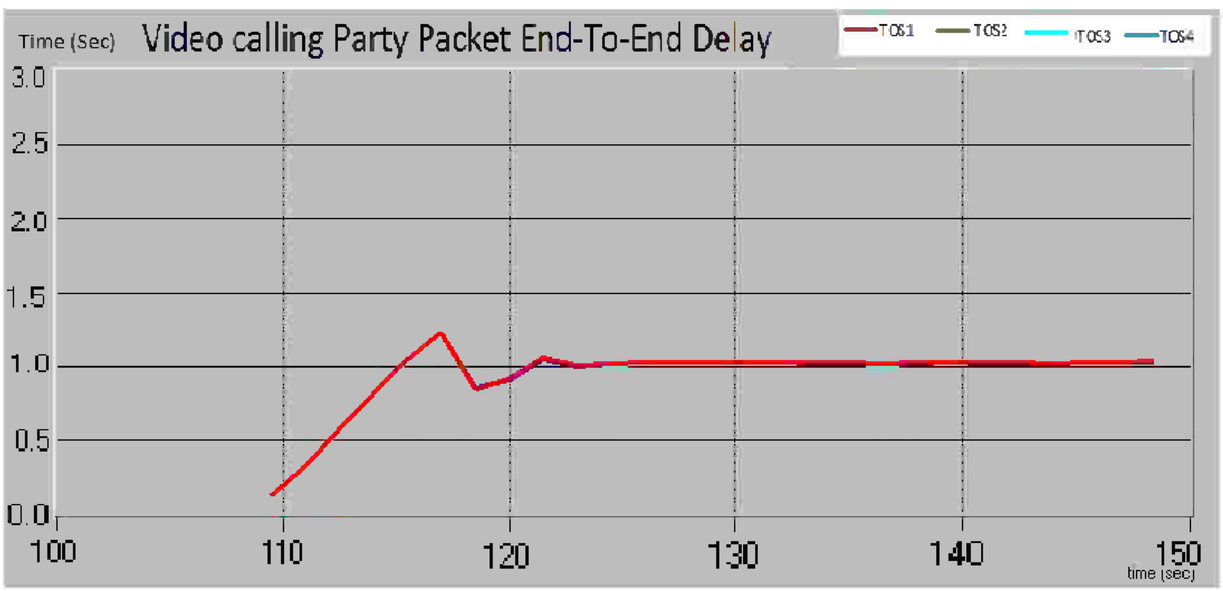

Figure 5.12delay in FIFO by using the RED algorithm.

Figure 5.11 and Figure 5.12 show the delay of video streaming for all types of service when using FIFO profile, without RED algorithm and using it successively. There are four graphs in each chart. The red graph shows the delay for TOS1, the green one deals with TOS2, the aquamarine graph shows the delay for TOS3, and the blue graph shows the delay for TOS4. As an overall trend, it is clear that the delay decreases rapidly by 55% when using

RED algorithm. The delay is constant because the queue is full and drop other packets received.

Table 5.6 FIFO Delay Enhancement.

	ToS1	ToS2	ToS3	ToS4
Improve Delay	*55%*	*55%*	*55%*	*55%*

From the Figure 5.12, Figure 5.13, and Table 5.6 we can conclude that delay decreaseswhen using RED algorithm by 55% for all ToSs.

5.3.1.2 FIFO First Input First Output Packets loss:

Traffic is queued in "router A". Since "router A" has limited buffer capacity, some packets are dropped when the buffer usage reaches its full capacity.

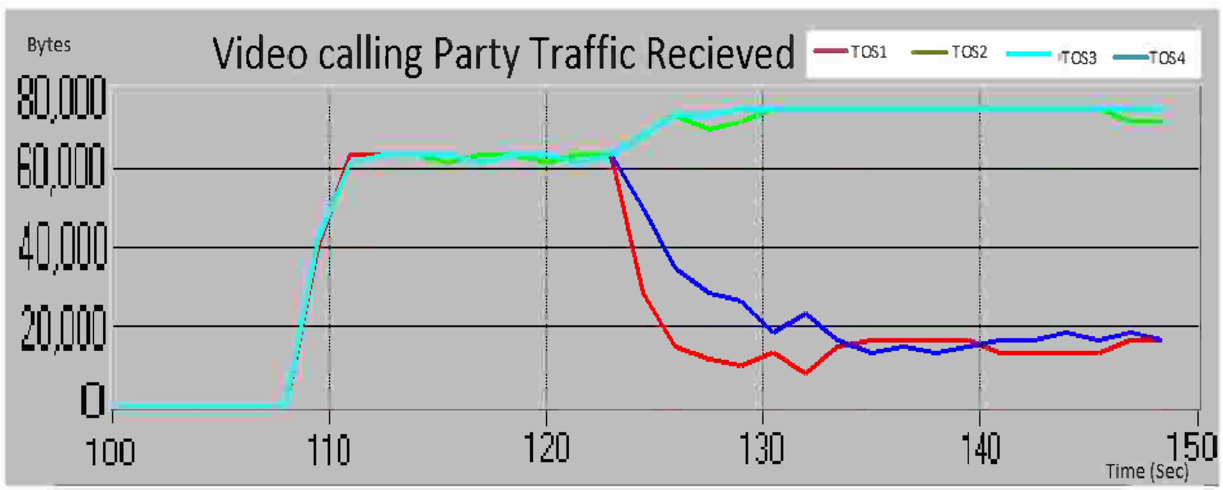

Figure 5.13Packets received without using RED algorithm.

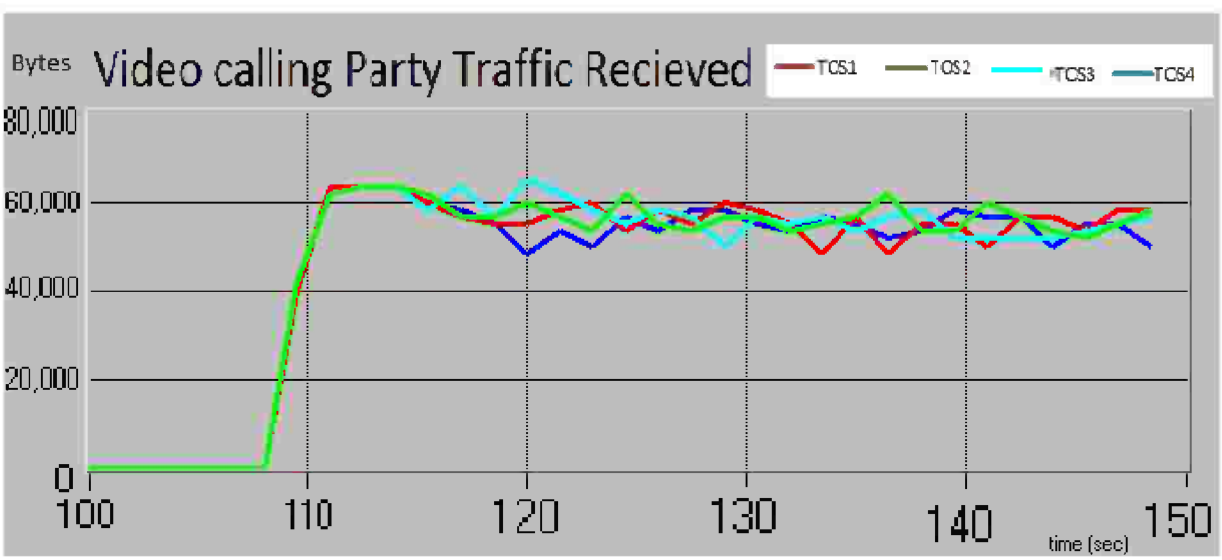

Figure 5.14Packets received by using RED algorithm.

Figure 5.13 and Figure 5.14 show the packetsreceived of video streaming for all types of service when using FIFO profile, without RED algorithm and using it successively.There are four graphs in each chart. The red graph shows the packets received for TOS1, the green one deals with TOS2, the aquamarine graph shows the packets received for TOS3, and the blue graph shows the packets received for TOS4. Without RED algorithm the packet received for ToS2, and ToS3 were significantly higher than ToS1, and ToS4. RED algorithm increases packet received for ToS1,ToS4 which improves system performance by making the percentage of packets received are almost equal for all ToSs.Table 5.7.

Table 5.7Results of effect RED algorithm on packet received in FIFO profile.

	ToS1	ToS2	ToS3	ToS4
Packets Sent	2003333	2003333	2003333	2003333
Packets Received (Without RED)	861666	1858333	1871667	965000
Packets Loss %(Without RED)	57%	7%	7%	52%
Packets Received (Using RED)	1511667	1521667	1526667	1488333
Packets Loss % (Using RED)	25%	24%	24%	26%

5.3.2 Influences of RED algorithmon Priority Queuing

5.3.2.1 Priority Queuing Delay:

Traffic is queued in "router A". Priority queuing mechanism differentiates between queues according to its priority. In this example, priority is based on Type of Service (ToS). Queue 4 sends packets as long it is not empty, Queue 3 sends packets when Queue 4 is empty, Queue 2 sends packets when Queues 3 and 4 are empty, and Queue 1 sends packets when all the other queues are empty. As a result of this classification traffic with higher ToS gets better delay.

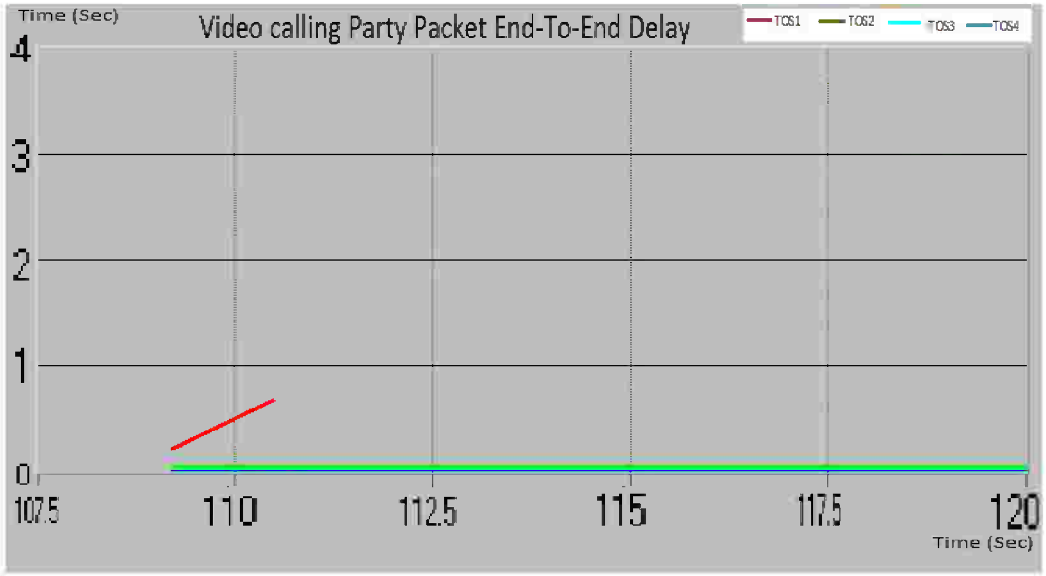

Figure 5.15Delay in PQ without using RED algorithm.

Figure 5.15 shows packet delay for PQ profile without using RED algorithm. There are four graphs in each chart. The red graph shows the delay for TOS1, the green one deals with TOS2, the aquamarine graph shows the delay for TOS3, and the blue graph shows the delay for TOS4. TOS1 only has the delay, because it is the lowest priority.

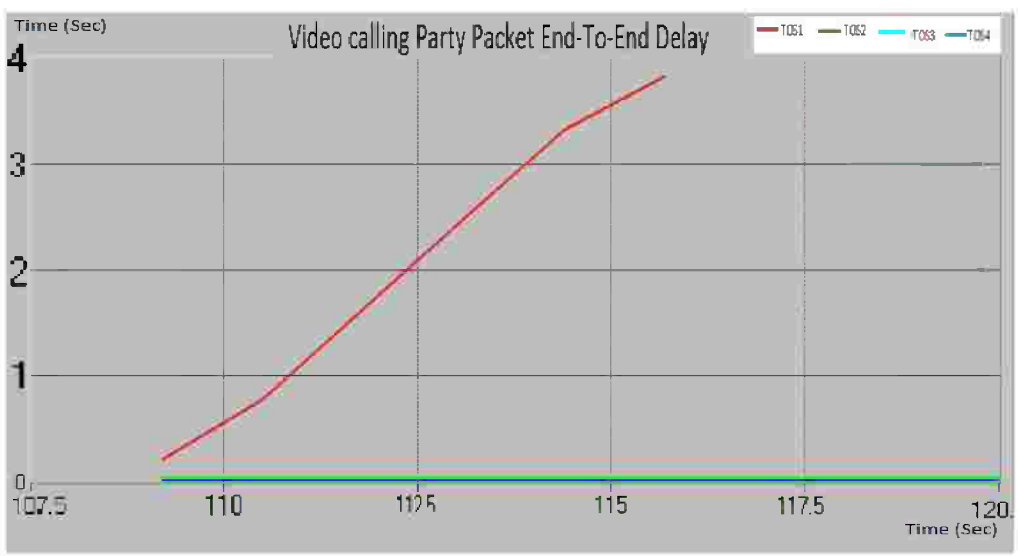

Figure 5.16Delay in PQ by using RED algorithm.

Figure5.15 andFigure 5.16 showthe delay of video streaming for all types of service.We can conclude that the delay without RED algorithm is the same when using it, but the packets delivered were increased when using RED algorithm for TOS1.

5.3.2.2 Priority Queuing Packet Loss

All packet loss must be in the lowest priority traffic, because queue 1 sends packets when all the other queues are empty.

Figure 5.17 shows the packets received statistics for Video conferencing without using the RED algorithm.The red graph shows the delay for TOS1, the green one deals with TOS2, the aquamarinegraph shows the delay for TOS3, and the blue graph shows the delay for TOS4. It is observed that the packets received increase in all type of services except ToS1.

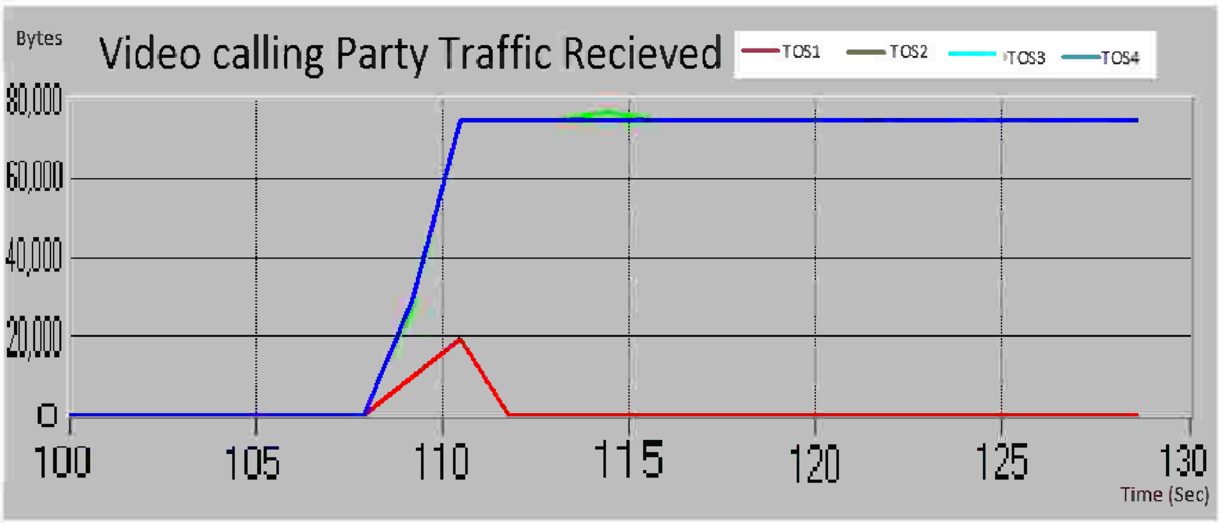

Figure 5.17Packet received without using RED algorithm.

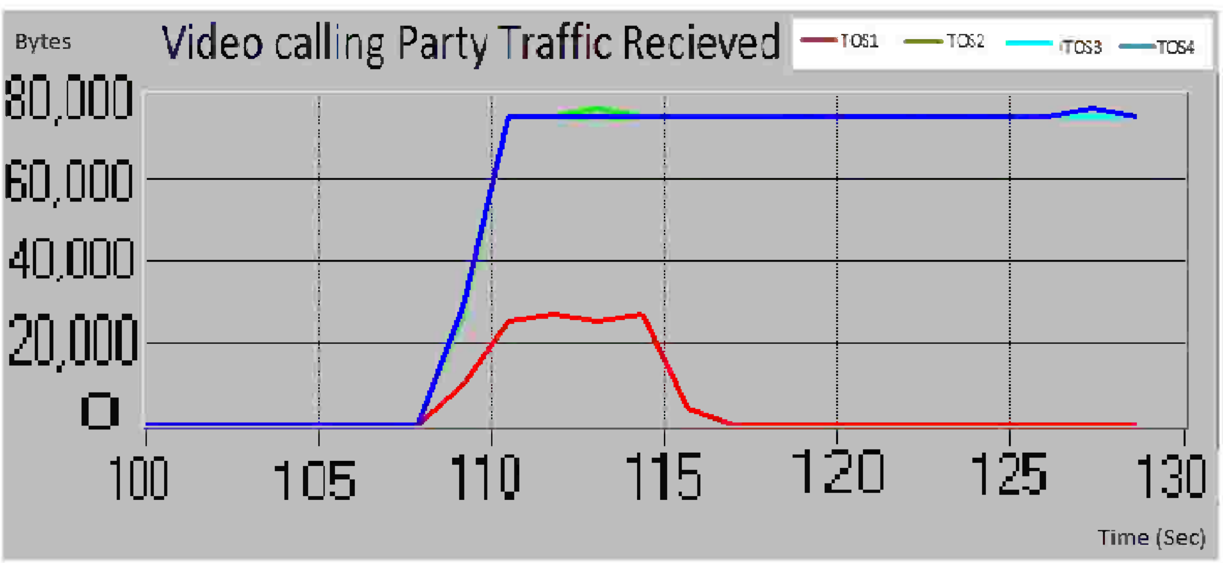

Figure 5.18Packet received by using RED algorithm.

Figure 5.18 shows the traffic received statistics for Video conferencing by using the RED algorithm. It is observed that the traffic increases in ToS1 by using RED algorithm.

Figures 5.17 and 5.18 compare the received signal before and after using the RED algorithm. In conclusion, we can see that the packets received for TOS1 increased when using RED algorithm.

Table 5.8 Results of effect RED algorithm on packet received in PQ profile.

	ToS1	ToS2	ToS3	ToS4
Packet Sent	1155769	1155769	1155769	1155769
Number of Packet Received (Without RED)	28846.15	1153846	1153846	1153846
Number of Packet Loss %(Without RED)	98%	0%	0%	0%
Number of Packet received (By using RED)	117307.7	1153846	1153846	1155769
Number of Packet Loss % (By using RED)	90%	0%	0%	0%
Improve Packets loss	8%	0%	0%	0%

Table 5.8 shows that the effect of RED algorithm on packets received in PQ profile. It is obvious that the packets loss decreased by 8% for ToS1.

5.3.3 Influences of RED algorithmon Custom Queuing

5.3.3.1 Custom Queuing Delay

As a result of this classification traffic with higher ToS gets better delay. Queue 3 and 4 get their share but let other queues starving of bandwidth.

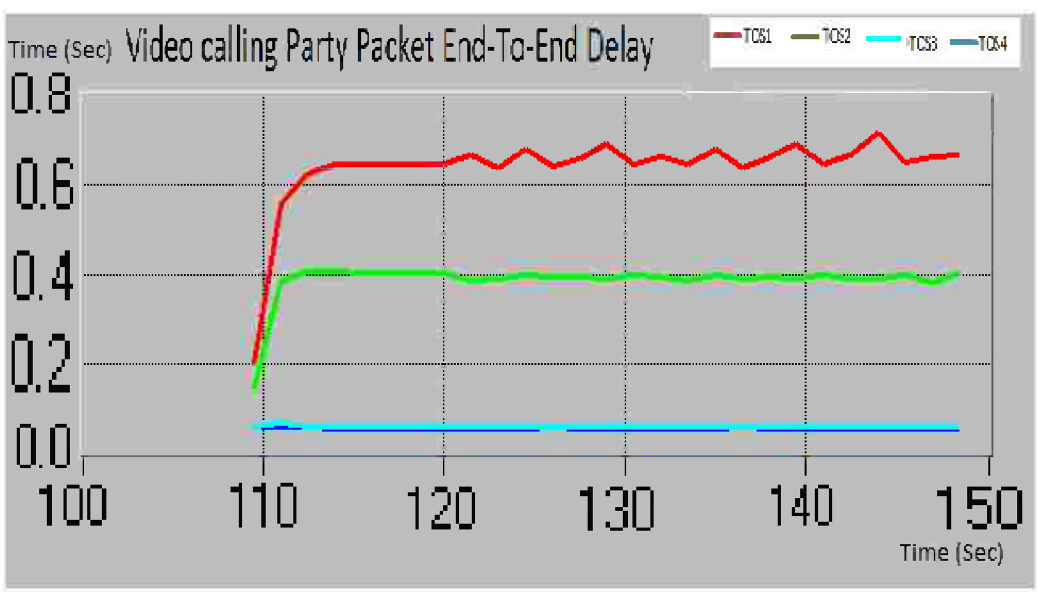

Figure 5.19Delay in CQ without using RED algorithm.

Figure 5.19 shows packet delay for CQ without RED algorithm. As the time or traffic increases the highest delay is experienced by the ToS1 then ToS2,ToS3 and ToS4 have very low delay.

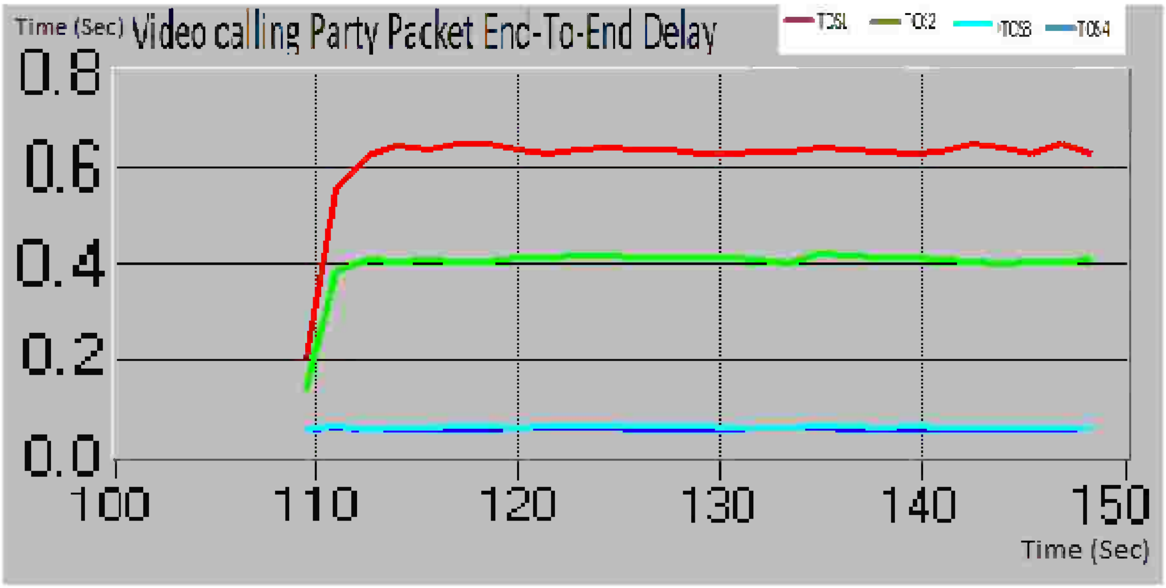

Figure 5.20Delay in CQ by using RED algorithm.

Figure 5.20 shows the effect of RED algorithm on the delay for all ToS. From Figure 5.19 and Figure 5.20, we can note that the delay is almost the same without using the RED algorithm and by using it.

5.3.3.2 Custom Queuing Packet loss

Queues send traffic proportionally to their byte count. In this example, queues with high index have higher byte count. Figure 5.21 shows the traffic received statistics for Video conferencing without using the RED algorithm. It is observed that the packets received increases in all types of services except ToS1 and ToS2,because Queues3 and 4have higher byte count.

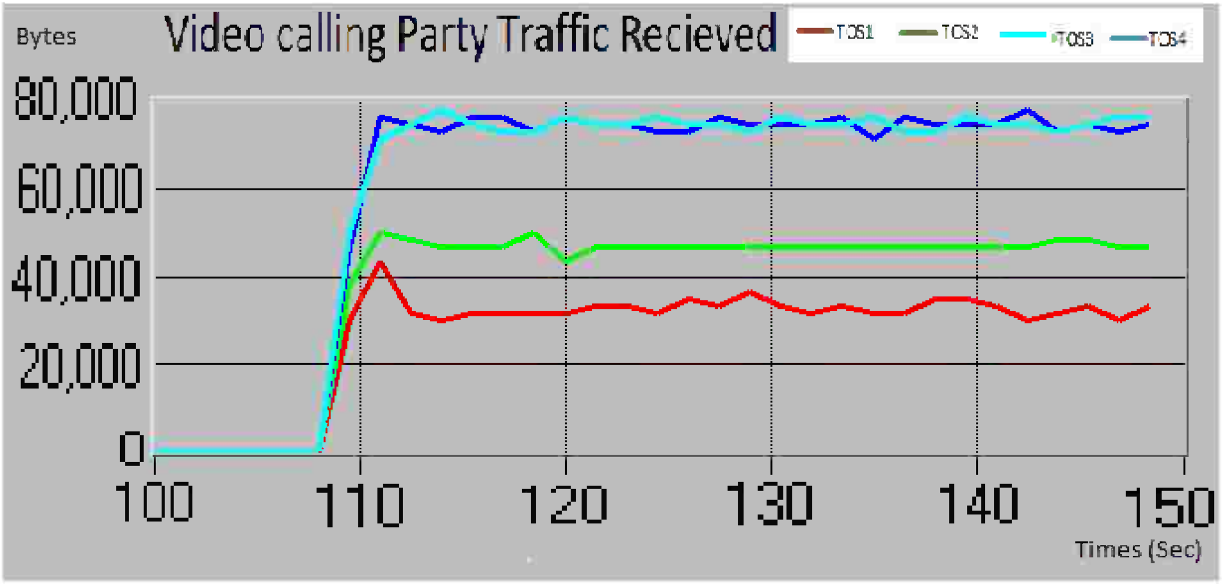

Figure 5.21Packet received without using RED algorithm.

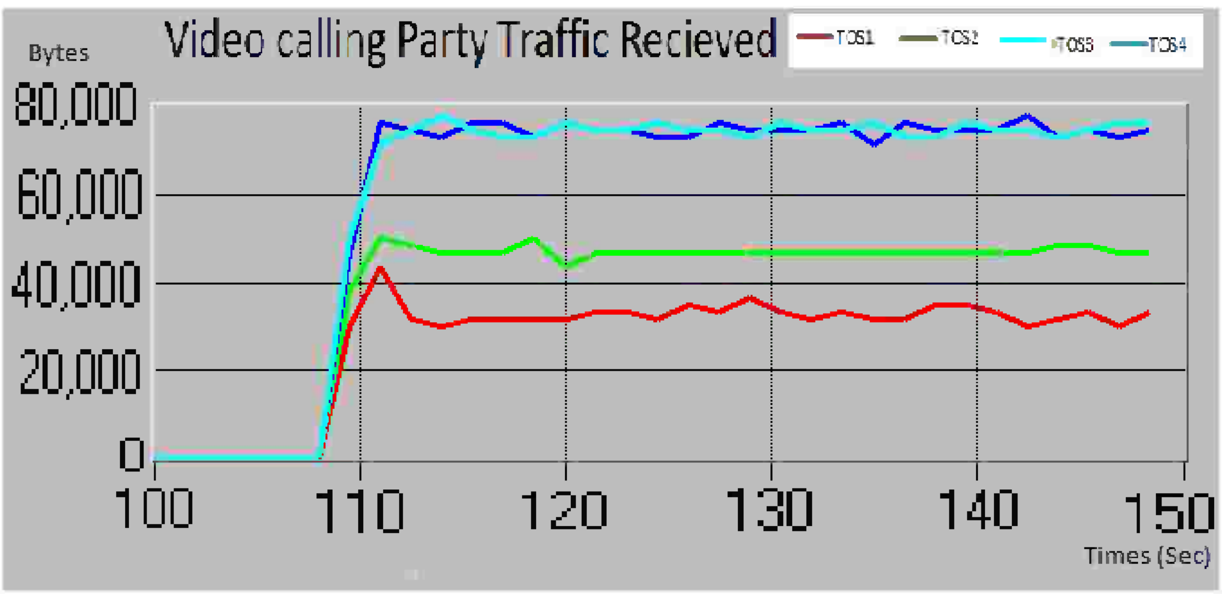

Figure 5.22Packet received by using RED algorithm.

Figures5.21 and Figure 5.22 show the effect of RED algorithm on the packets received for all ToSs. We can note that the packets receivedare almost the same without using RED algorithm and by using it.

5.3.4Influences of RED algorithmon Weighted Fair Queuing

WFQ discipline classifies packets by queue. WFQ uses multiple queues to separate flows and gives the flows equal amounts of bandwidth. This prevents the FTP from consuming all available bandwidth. WFQ allows a weight to be assigned to each queue. The weight controls the percentage of the link's bandwidth each queue will get. WFQ discipline sorts packets in weighted order of arrival of the last bit, to determine the transmission order. (ToS) bits could be used in the IP header to identify that weight. WFQ is aware of packet sizes and can support variable sized packets, so that flows with large packets are not allocated more bandwidth than the queues with smaller packets[12].

5.3.4.1Weighted Fair Queuing Delay

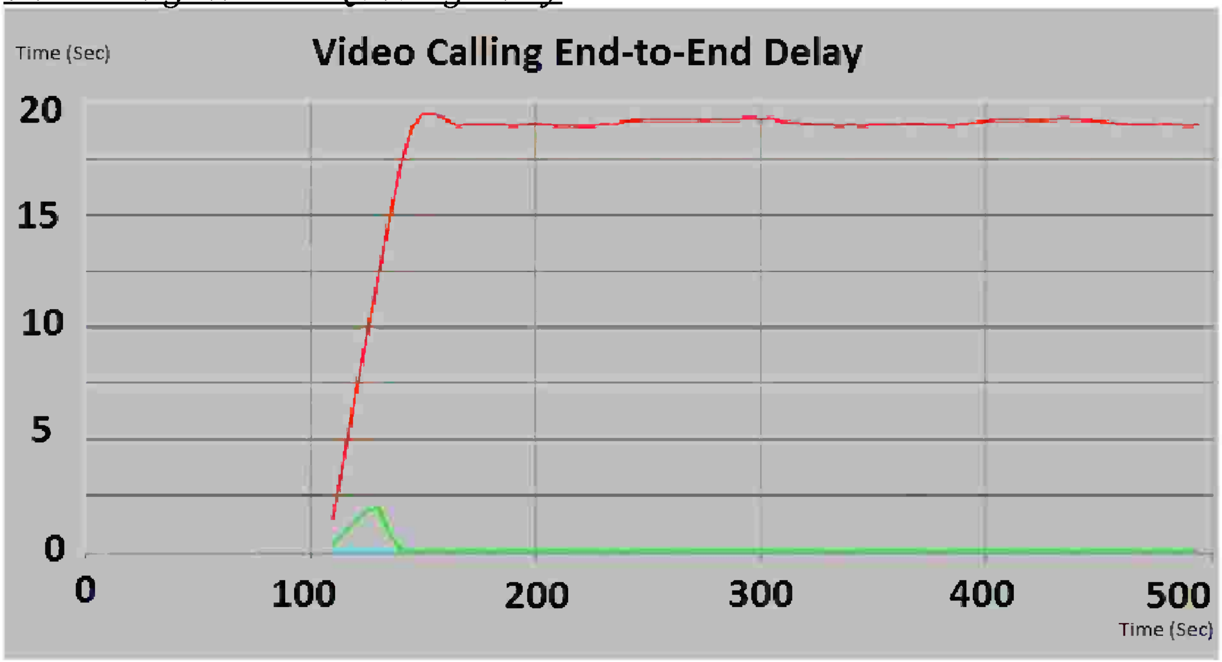

Figure 5.23Delay in WFQ without using RED algorithm.

Figure 5.23 shows packets delay for WFQ withoutusing RED algorithm. The red graph shows the delay for TOS1, the green one deals with TOS2, the aquamarinegraph shows the delay for TOS3, and the blue graph shows the delay for TOS4. TOS3 and TOS4 are identical.

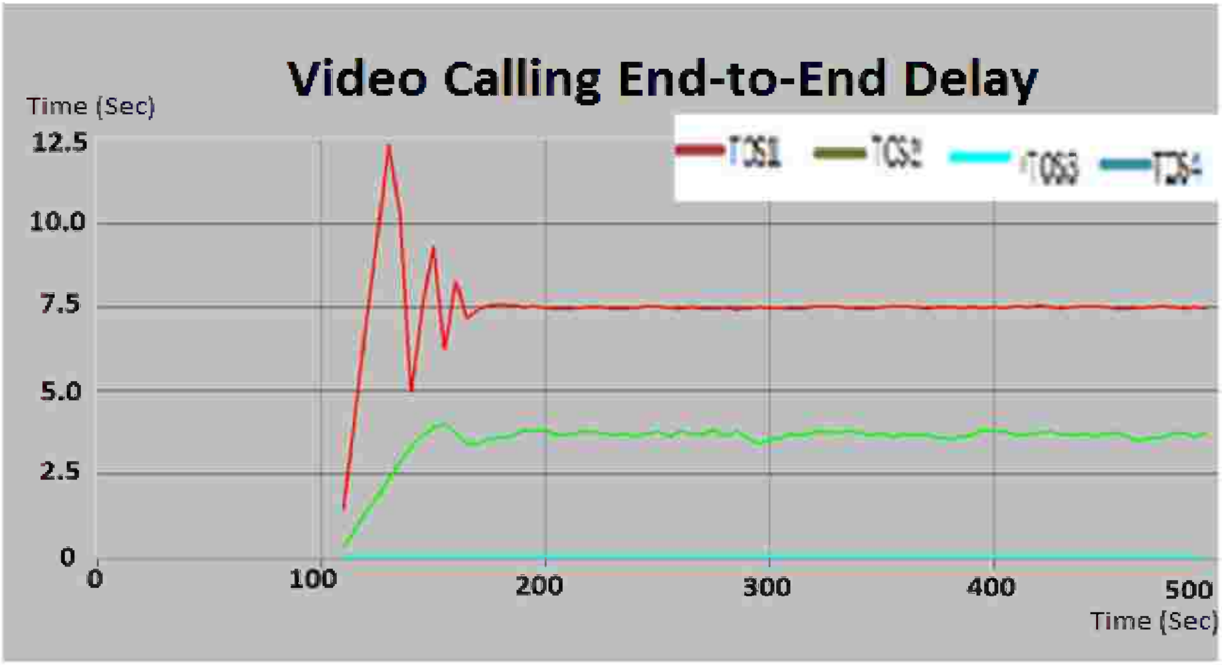

Figure 5.24Delay in WFQby using RED algorithm.

Figure5.23 and Figure 5.24 show the delay of video streaming for all types of services, without RED algorithm and using it successively.We can note that the delay for ToS1decreased after using RED algorithm, but the delay has slightly increased for ToS2 when using RED algorithm.TOS3 and TOS4 are identical.

5.3.4.2Weighted Fair Queuing Packet loss

Figure 5.25 shows the traffic received statistics for Video conferencing without the RED algorithm, where it is observed that as the packets received increase in ToS3 and ToS4, but packets receiveddecrease in ToS1 and ToS2.

Figure 5.25Packets received without using RED algorithm.

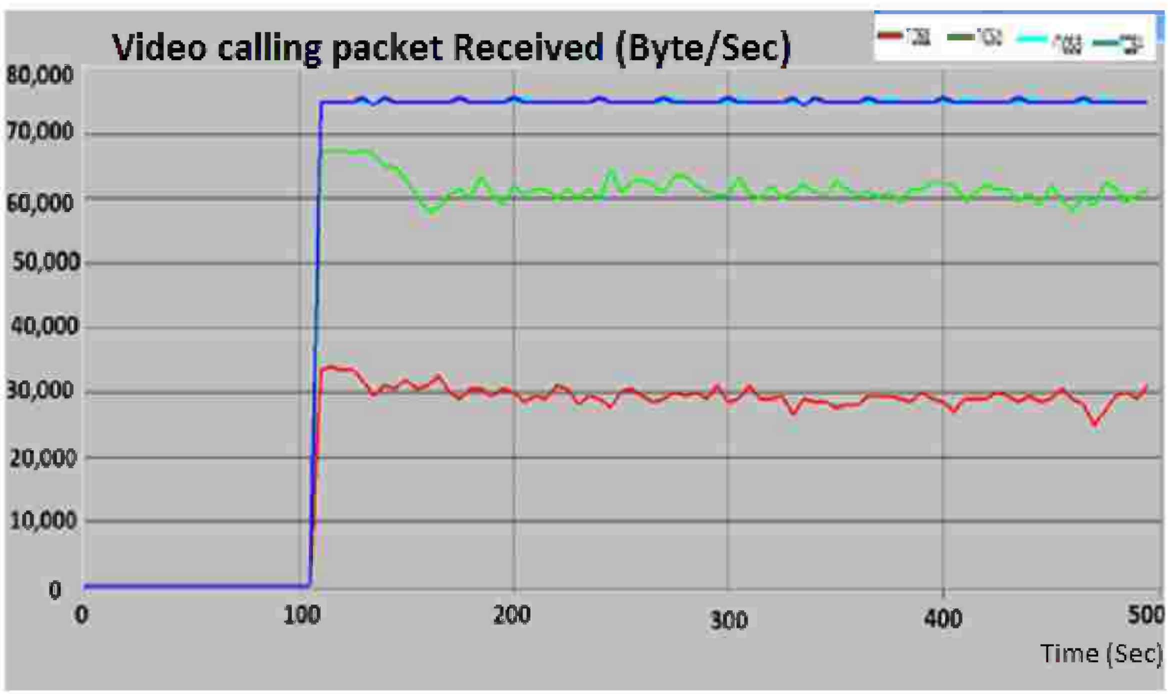

Figure 5.26Packets received byusing RED algorithm.

Figure 5.25 and Figure 5.26 show the effect of RED algorithm on the packets received for all ToSs. From previous figures, we can note that the packets received increase for all ToSs except for ToS3by using RED algorithm.

5.4Comparative Study of Different Queuing Scheduling Disciplines

In this simulation model, The OPNET software is used to build a small IP network and then to exam the effect of different queuing scheduling disciplines with different kind streaming applications: FTP, Video, and VoIP, on packet delivery and delay on the network. The network topology of the model is designed from two LANs, one consisting of different streaming clients and the other consisting of the corresponding servers as shown in Figure 5.27 The simulation network model is used to collect statistics to do the performance analysis based on IP protocol (traffic dropped in packets/sec), Video conferencing (traffic received in packets/sec), and Voice (traffic received in bytes/sec).

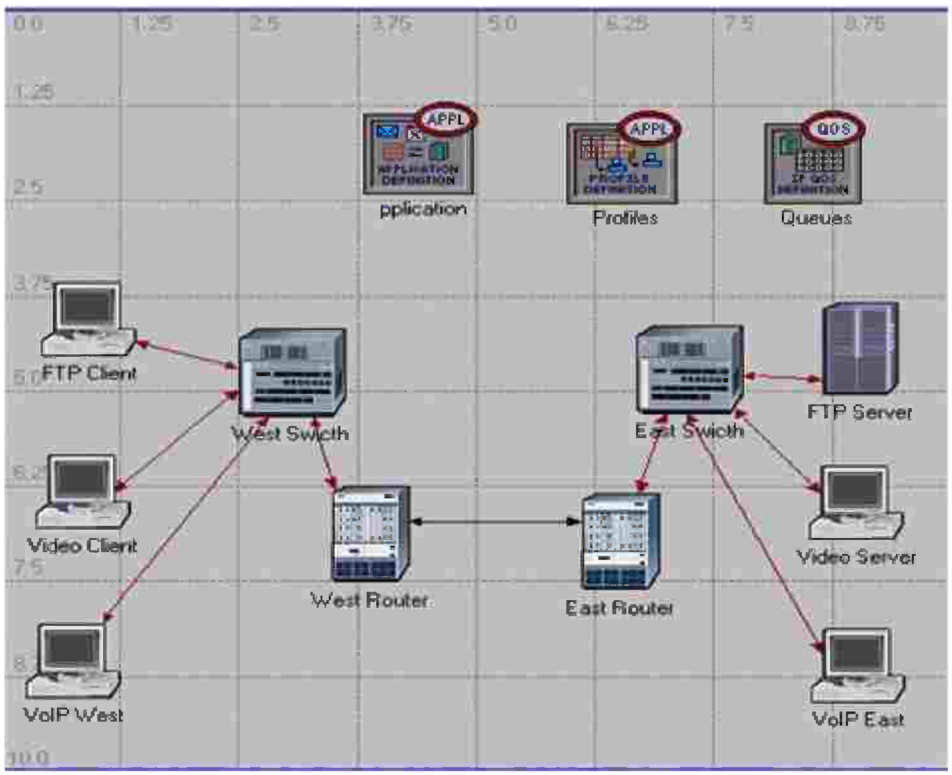

Figure 5.27 The network topology of the model[12].

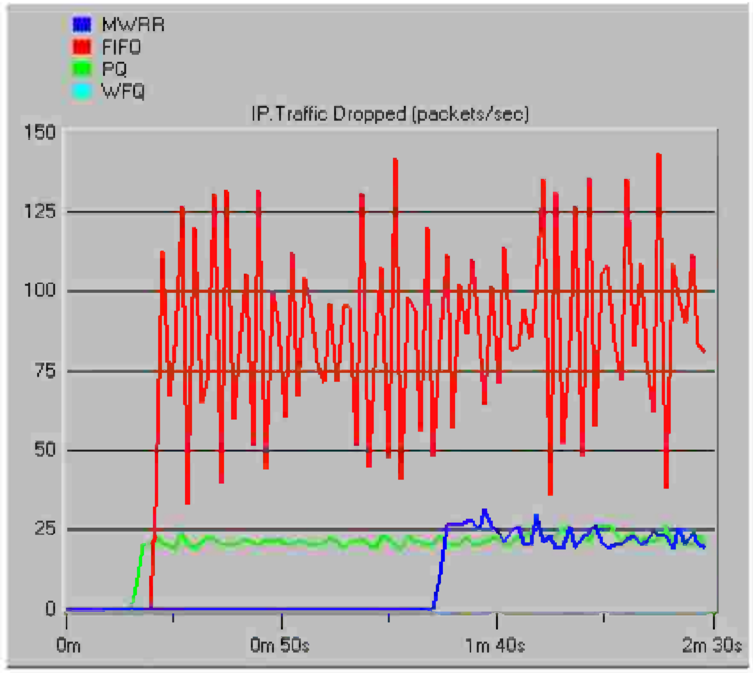

Figure 5.28 IP traffic packet drops (packets/sec)[12].

Figure 5.28 shows the dropped IP data packets for the four queuing scheduling disciplines as a function of time in seconds. The Figure shows that the highest rate of dropped packets occurs with the FIFO queuing scheduling discipline. PQ is lower and then followed by MWRR. The lowest rate is provided by the WFQ queuing scheduling discipline where there is no packet drop.

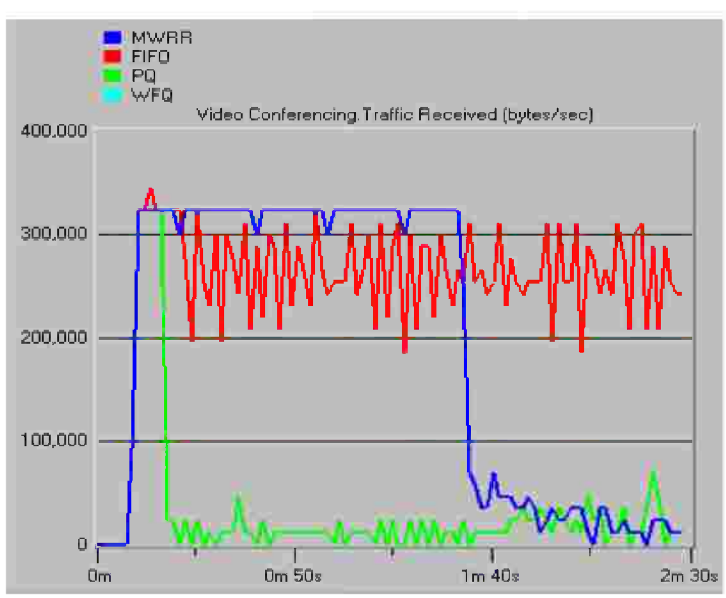

Figure 5.29Video-conferencing traffic received (bytes/sec)[12].

Figure 5.29 shows the traffic received statistics for Video conferencing, where it can be observed that in cases of MWRR, FIFO, PQ, and WFQ video receiving rate graph is not observed, where PQ starts high, then continues very low, but MWRR begins at a higher rate than FIFO, then becomes low with passing time, and FIFO stays high.

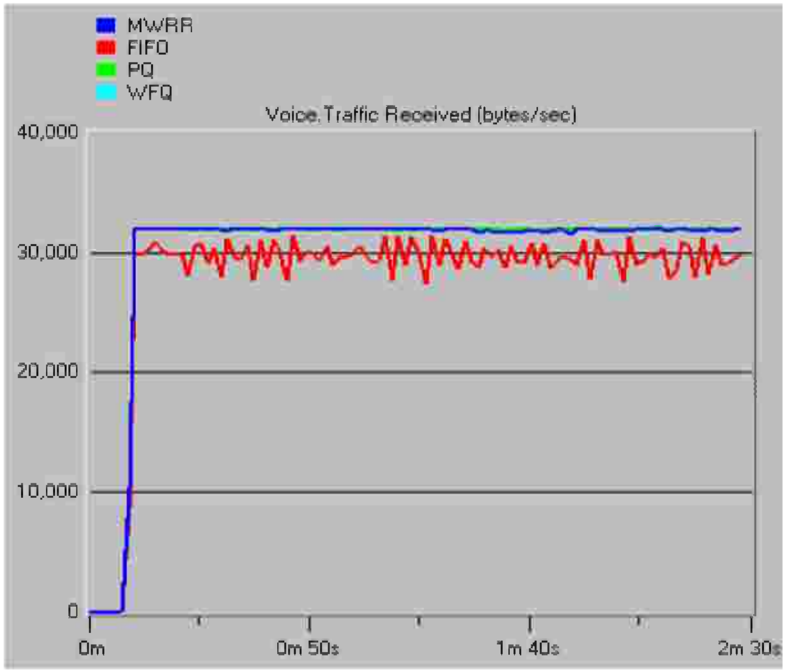

Figure 5.30 Voice traffic received (bytes/sec)[12].

Figure 5.30 shows traffic received statics for VoIP, where it is observed that as the traffic increases the performance graph increases in all the queuing scheduling disciplines. However, the performance graph of FIFO is lower than those of MWRR, PQ, and WFQ [12].

Figure 5.31 Video-conferencing traffic received for ToS1 (bytes/sec).

Figure 5.31 shows the traffic received statistics for Video conferencingas a function of time in seconds. It can be observed that in cases of CQ, FIFO, PQ, and WFQ video receiving rate graph uses ToS1. For both WFQ and FIFO, packets received starts high and then dropped but still higher than PQ.

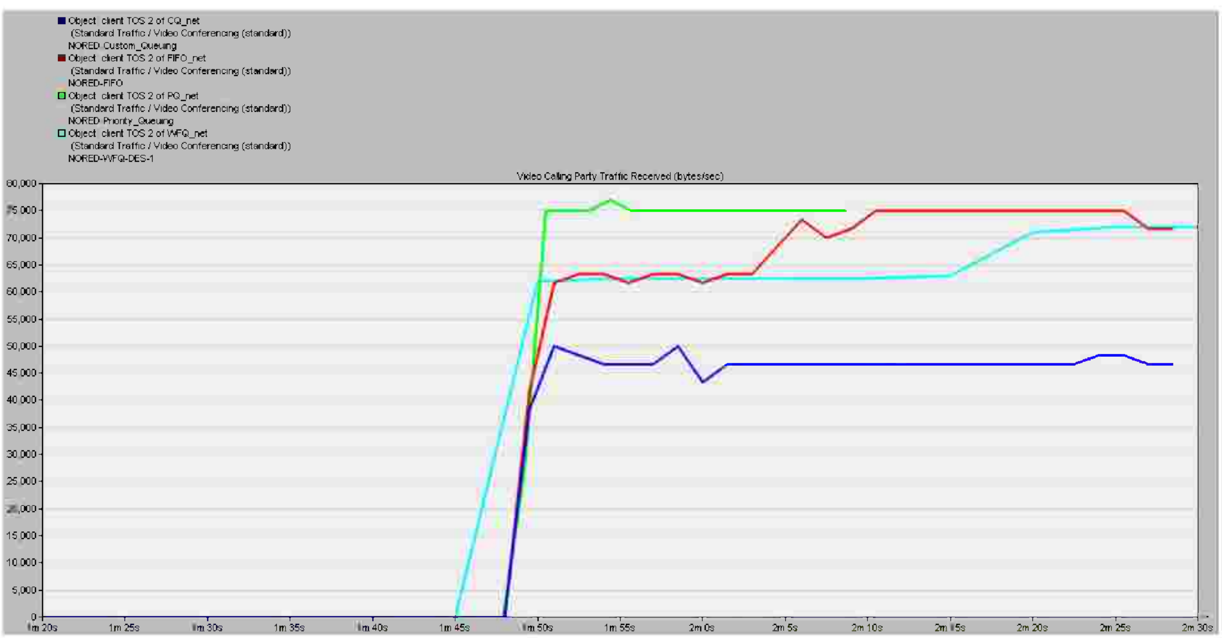

Figure 5.32 Video-conferencing traffic received for ToS2 (bytes/sec).

Figure 5.32 shows the traffic received statistics for Video conferencing, where it can be observed that in cases of CQ, FIFO, PQ, and WFQ video receiving rate graph uses ToS2. PQ has the best performance while CQ has the worst performance.

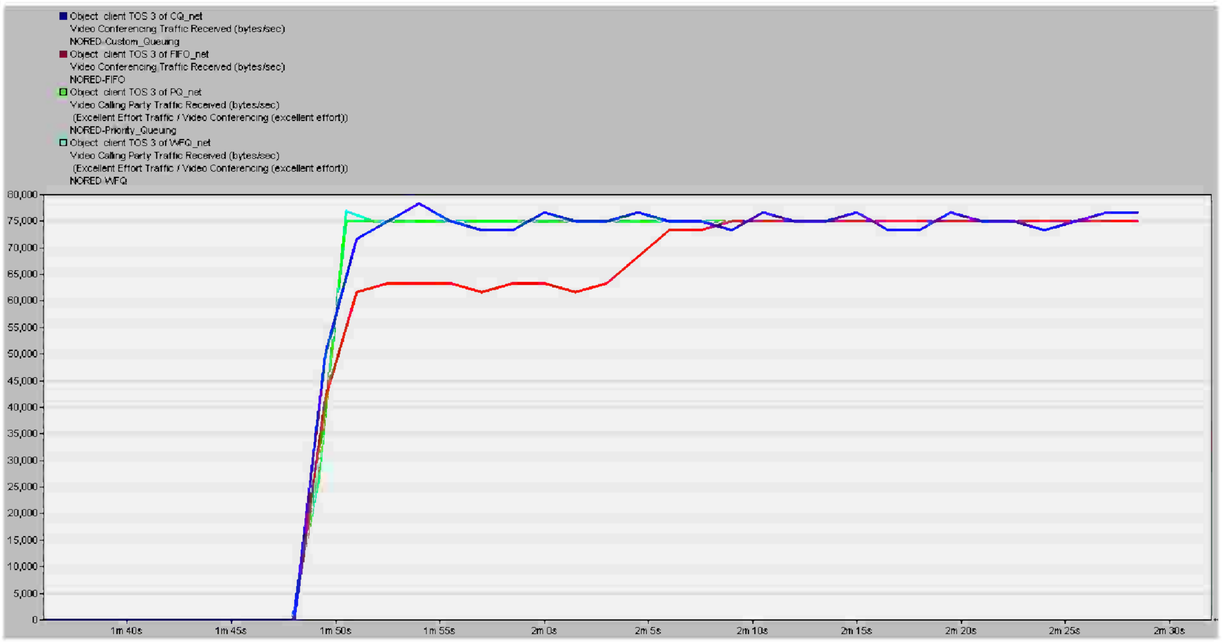

Figure 5.33 Video-conferencing traffic received for ToS3 (bytes/sec).

Figure 5.33 shows the traffic received statistics for Video conferencing. It can be observed that in cases of CQ, FIFO, PQ, and WFQ video receiving rate graph uses ToS3 and all have the approximately the same packets loss performance.

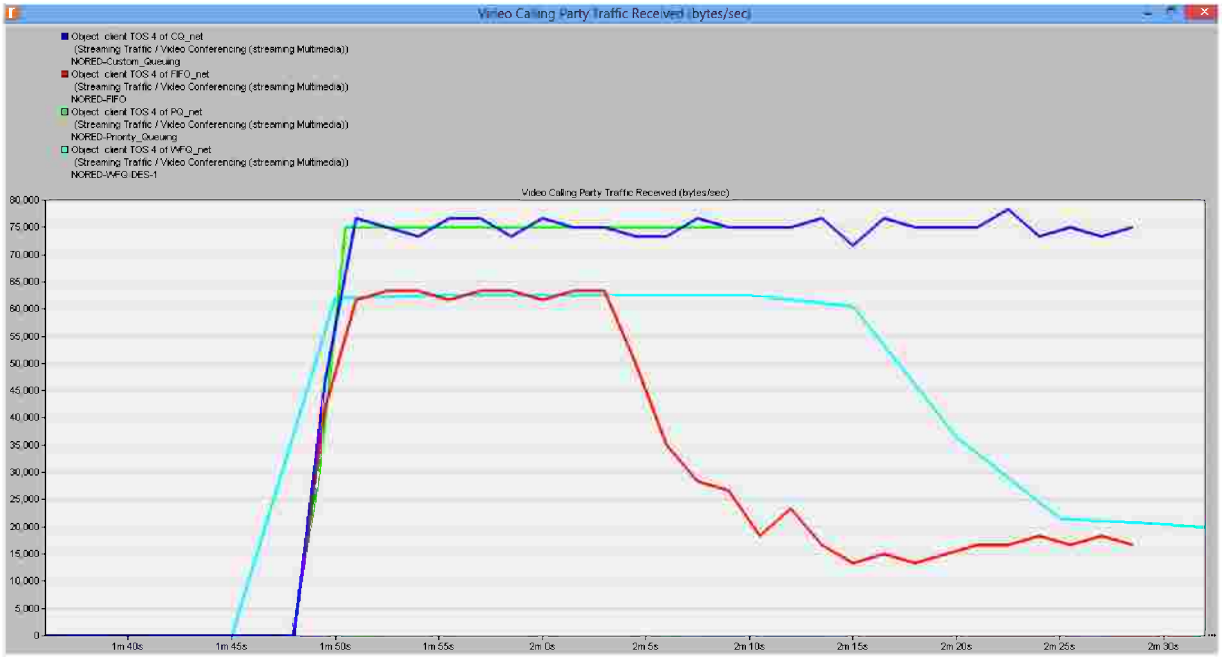

Figure 5.34Video-conferencing traffic received for ToS4 (bytes/sec).

Figure 5.34 shows the traffic received statistics for Video conferencing. It can be observed that in cases of CQ, FIFO, PQ, and WFQ video receiving rate graph uses ToS4. PQ and CQ have better performance than FIFO and WFQ regarding packets received.