The effects of different queuing techniques over VoIP performance: a simulation approach

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Abstract. **This paper presents one of the features of DS (Differentiated Services) architecture, namely the queuing or congestion management. Packets can be placed into separate buffer queues, on the basis of the DS value. Several forwarding policies can be used to favor high priority packets in different ways. The major reason for queuing is that the router must hold the packet in its memory while the outgoing interface is busy with sending another packet. Our main goal is to compare the performance of the following queueing mechanisms: FIFO (First-In First-Out), CQ (Custom Queuing), PQ (Priority Queuing), WFQ (Weighted Fair Queuing), CBWFQ (Class Based Weighted Fair Queuing) and LLQ (Low Latency Queuing).**

1.1. Introduction. At the beginning computer networks were designed mainly for data transfer such as FTP and email, where delay was considered to be unimportant. In most cases the delivery service was effective, and the TCP protocol dealt with data losses. As the multimedia applications became popular (voice transfer, video conferences), separate telephone and video communication networks were set up. Nowadays, office and company networks are transformed into one converged network (see [1]), in which the same network infrastructure is used to ensure all the requested services.

Although converged networks have many advantages, there are some disadvantages too, namely the competition for network resources (buffers of routers), which leads to congestion. Delay in delivering the packets, jitter, loss of packets are all consequences of congestion. Not each application is sensitive to these issues. For example, FTP is not impacted by delay and jitter, whereas the multimedia applications (video, voice) are very sensitive to them and the loss of packets too. QoS was introduced to handle this problem, and it is able to provide better multimedia performance (see [2]).

In the IP header there are some fields which can be used to make distinction between the packets of different applications, for example the Type of Service field. Different technics such as congestion management (PQ, CQ, WFQ, CBWFQ, LLQ), prevention of congestion (WRED), resource efficiency insurance (fragmenting the packets, and compressing), traffic shaping and traffic policing are used by the QoS technology in order to control data traffic. This article focuses on the most important component, the congestion management.

Speed mismatches and path aggregations (see [1]) are the main causes of congestion in computer networks. There are different algorithms which can overcome the mentioned problematic situations. Our purpose is to analyze and evaluate the efficiency of these algorithms using simulations. We are going to examine the following methods: FIFO, PQ, CQ, CBWFQ, WFQ and LLQ. It is important to note that these algorithms have real effect only in case of congestion (see [3]).

The OPNET IT Guru Academic Edition (see [4]-[6]) was used to perform the simulation. The network topology for the testing is identical with the one occurred in former articles (see e.g. [6]-[8]). In this paper we continue to study the queueing technologies for congestion management. In [7] and [8] the authors considered three algorithms: FIFO, PQ and WFQ. The conclusion was that WFQ is the most efficient for multimedia applications. In addition to these we investigate three new algorithms: CQ, CBWFQ and LLQ. The main result of this paper is that for multimedia applications (mainly voice transfer) LLQ is more efficient then WFQ.

The mentioned algorithms has been examined in several papers (see e.g. [10]).

1.2. Simulation environment and settings. We used the following network topology in OPNET IT Guru Academic Edition:

The measurement environment consists of 2 routers, 2 switches and 6 hosts. The routers are connected with a point-to-point link, having the speed of *ppp-DS1*. The rest of the hosts are connected with *10BaseT*. The part between the two routers is actually a narrow cross-section where congestion can happen. For this reason the congestion management algorithm is activated in this area (see [11]-[12]).

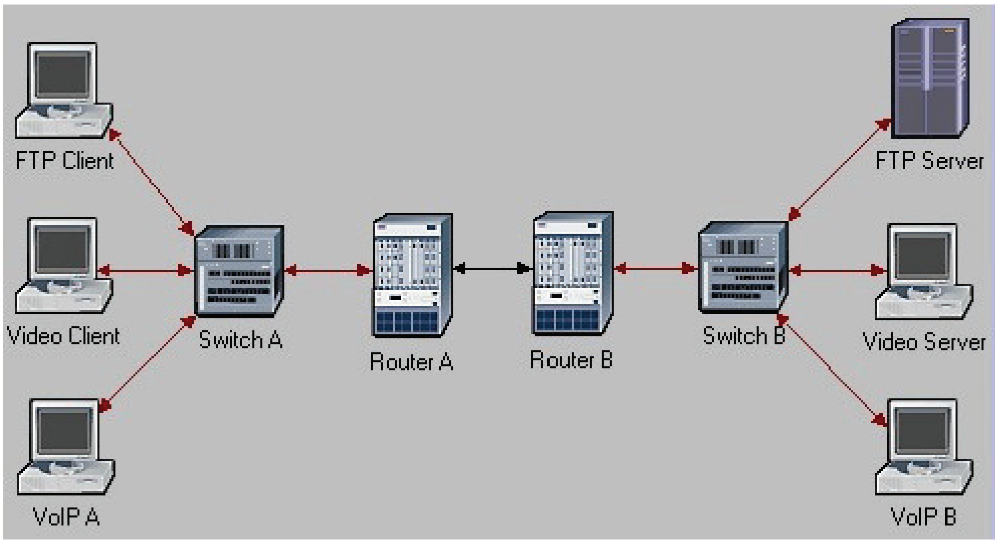

Figure 1 Simulation network topology

1.3. Simulation results. Simulation makes possible to perform several measurements and statistical analysis. The following main indicators are investigated: the packet loss rate, the number of received packets, the delay of packets between the endpoints and jitter. The length of the simulation was 5 minutes in each case. Congestion management algorithms are activated only in the case of congestion. The graph below presents this fact: it is the 105th second when the congestion management algorithm becomes active and its performance study can be started. Figures 2-7 show the results of the simulation.

The highest rate of packet loss (see Fig.2.) was produced by the FIFO rule, as it could be expected. In the case of PQ, the loss of audio packets is zero, due to the existence of the highest priority queue. The loss of video and FTP packets is extremely high in this case (see Fig.3.), as the highest priority queue (voice traffic) blocks the video and FTP communication. Using CQ we can get better results than using PQ, concerning the packet loss, but it requires a lot of fine-tuning work. WFQ, CBWFQ and LLQ are the most efficient mechanisms concerning the packet loss.

In the case of voice communication there were examined the following performance parameters: the number of received voice packets, the delay of voice packets and the variation in the delay of voice packets (see Fig.3-7). Concerning the number of received voice packets the performance of the PQ, WFQ, CBWFQ and LLQ mechanisms is the most efficient. CQ and FIFO show a bit worse results but they are acceptable too. Interactive voice communication requires a maximum of 150 ms delay for voice packets (see [13]). FIFO and CQ cannot fulfill this criterion. QoS also requires that the jitter do not exceed 30ms. FIFO and CQ didn't fulfill this criterion too.

Finally, the four most efficient algorithms (PQ, WFQ, CBWFQ, LLQ) were compared in respect of the delay of voice packets and jitter. The reason of choosing the voice packets is that they are very sensitive to delay and jitter. The result is interesting (see Fig.5 and 7.). Previous articles (see e.g. [6]-[7]) showed that WFQ is the most efficient for voice packets. It can be observed that WFQ and CBWFQ have the highest dispersion for the delay. WFQ has the highest value for jitter, much higher than in the case of PQ and LLQ. It is obvious (see Fig.5. and 7.) that LLQ has much better performance for voice packets than WFQ.

1.4. Conclusions. In this paper * we tried to present a short overview of congestion management algorithms used by routers. We managed to evaluate three more algorithms beside the ones published in former articles (see e.g. [6]-[7]). The simulation environment was provided by the OPNET IT Guru Academic Edition application, based on mathematical models. We used a generalized, extendable and factual network topology. The article concludes that LLQ is the most efficient algorithm for voice

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FIGURE 2 IP packet loss

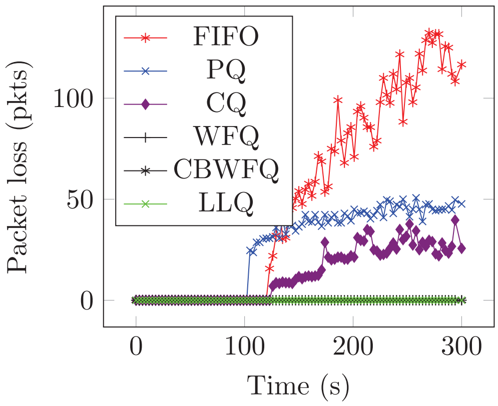

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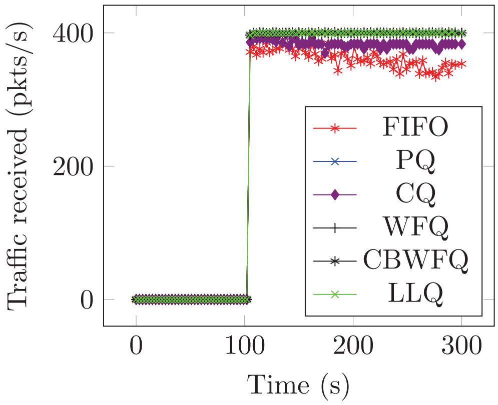
FIGURE 3 VoIP: Packet received



data transfer. Our next research topic is to examine and test the algorithms presented in the current article in a real network environment, as it is also a widely used by reasearchers (see e.g. [14]) to perform traffic measurements.

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FIGURE 4 VoIP: Traffic delay

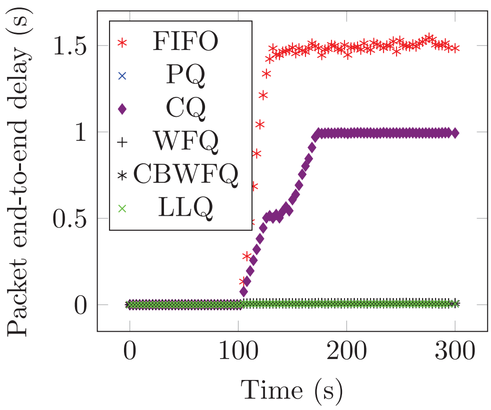

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FIGURE 5 VoIP: Traffic delay for PQ, WFQ, CBWFQ and LLQ

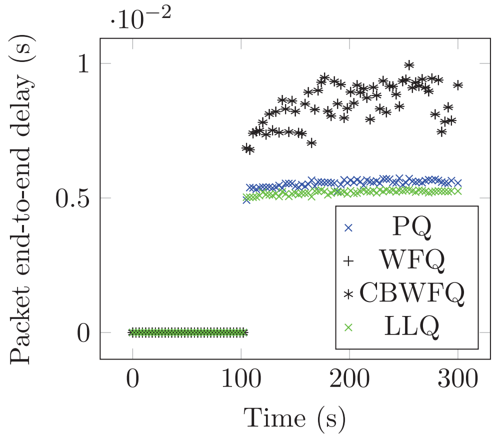

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Figure 6   VoIP: Traffic jitter

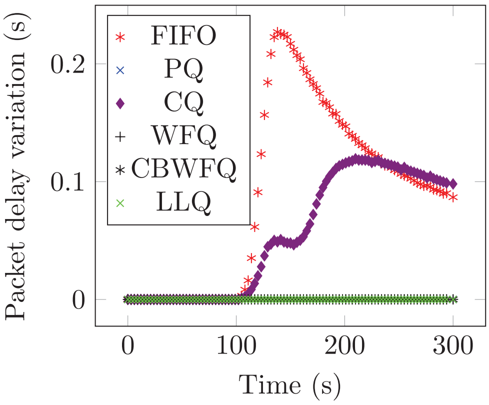

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Figure 7   VoIP: Traffic jitter for PQ, WFQ, CBWFQ and LLQ