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A COMPARATIVE STUDY OF SOME QUEUE MANAGEMENT METHODS USED FOR CONGESTION CONTROL IN WIDE AREA NETWORKS

BY

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Abstract. A comparative study of some queue management methods (First-In First-Out, Priority Queuing and Custom Queuing) is presented. A real-time network application, videoconference, with special QoS (Quality of Service) requests of throughput, end-to-end delay and packet loss is considered. Optimization is carried out based on differentiating the quality of services according to the priority of the nodes for collision control and avoidance. A network simulator program is used to illustrate the performances of these algorithms.

Key words: queue management; congestion control; QoS; real-time application.

1. Introduction

Congestion is a phenomenon which occurs in WANs (Wide Area Networks), usually caused by the limited bandwidth of the communication channel and the increased bandwidth demand of some network applications. The LANs (Local Area Networks) offer a larger bandwidth on short distances and the network architecture usually avoids congestion. In WAN, things are different. Many users share the same communication channel and the cumulated

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bandwidth requests can overrun the channel capacity because of local buffer overflows. A slow network connection which strangulates the traffic is described as a “bottleneck” path which maintains a constant flow no matter how much data is coming to the input (Fig. 1). Long queues of packets occur and information loss is possible if the amount of data is so high that the transmission buffers are saturated (Jacobson & Karels, 1988).

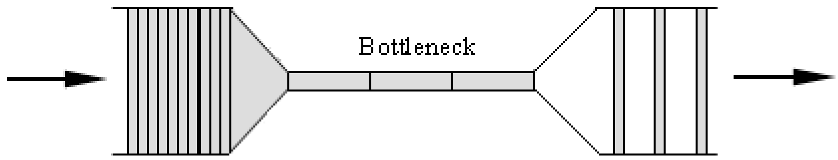

Fig. 1 – “Bottleneck” path.

Different queue management methods for TCP/IP (Transmission Control Protocol/Internet Protocol) networks are proposed in the literature (RFC 5681 – TCP Congestion Control): FIFO (First-In First-Out), PQ (Priority Queuing), PQ with LLQ (Low Latency Queuing), CQ (Custom Queuing), CQ with LLQ, WFQ (Weighted Fair Queuing), CBWFQ (Class Based Weighted Fair Queuing), PWFQ (Prioritized Weighted Fair Queuing) and others (Scripcariu & Diaconu, 2011; Diaconu *et al.*, 2011). All these are strictly related to congestion control and avoidance mechanisms used on wide-area networks.

Jacobson and Karels (1988) have studied the congestion problem and proposed some possible solutions to ensure QoS (Quality of Service) such as slow-start transmission.

Nowadays many multimedia applications run on a communication network. Many of them are real-time application (messenger, voice chat, video chat, etc.) and a lot of users are interested in video transmission. Videoconference is a real-time network service needing a large amount of bandwidth. QoS is a demand for the communication services especially for delay sensitive applications (Voice over IP and videoconferencing) (Rădulescu & Coandă, 2007).

Different service quality is provided by the network according to the class of service and the priority of the node.

The present paper addresses the study of some congestion control methods (FIFO, PQ and CQ) considering the videoconferencing service. It is also proposed a mechanism for differential bandwidth allocation and successive reduction of the video quality in order to avoid congestion and minimize the packet loss.

The paper is organized in four sections. Section **2** presents some congestion control methods and a comparison of their performances. Section **3** outlines the features of a new proposed mechanism with different video quality. Finally, some conclusions are emphasized in section **4**.

2. Queue Management Methods

A simple method of queue management is FIFO (First-In First-Out) which works on the principle: “first come – first served” (Fig. 2).

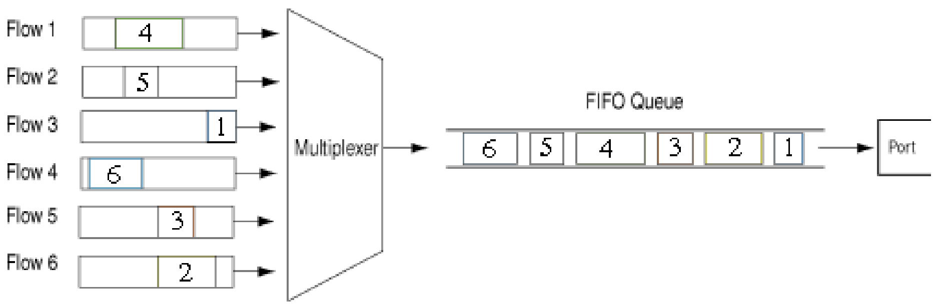

Fig. 2 – FIFO Mechanism.

All input packets are included in a queue and the delivery time depends on the length of the queue. No priority is used and no differentiation is made between packets and network services. No QoS warranty is offered by FIFO.

A large amount of data could cause the saturation of the buffer, network congestion and some packet loss. Increasing the buffer dimension and the queue length will create higher transmission delays. So, a compromise should be made in order to provide congestion control and good QoS.

FIFO requires low computation resources so it is fast but it does not avoid congestion and does not provide any QoS warranty.

Since the goal of the optimization process is to improve the quality of transmission with high throughput, low end-to-end delay and low packet loss rate, other queue management methods are in use.

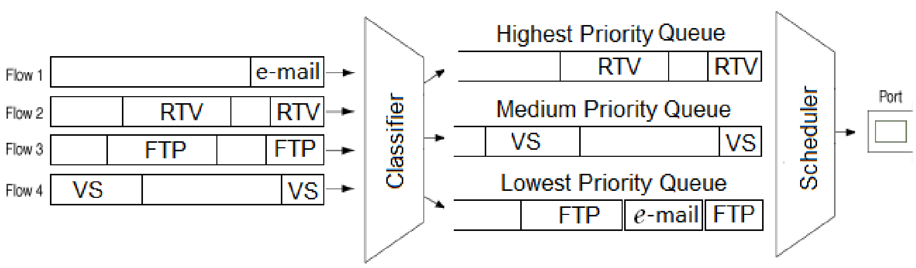

Fig. 3 – PQ Mechanism.

Priority queuing (PQ) is a queue management method based on priorities as it is illustrated in Fig. 3. Each packet is classified according to the class of service to which it belongs and it is delivered to the corresponding queue. The highest priority is associated with real-time (RT) services such as voice (VoIP – Voice over Internet Protocol) or video conferencing (RTV – Real-Time Video) applications. A medium priority can be given, for example, to a video streaming (VS) with no delay constraints. Low priority is offered to different services and protocols such as electronic mail (*e*-mail), file transfer (FTP – File Transfer Protocol), Web browsing (HTTP – Hypertext Transfer Protocol) and other applications with minimum QoS requirements.

A scheduler block will transmit the packets in the descending order according to the priorities. The packets with highest priority are forwarded before the medium priority packets and these are transmitted before a lower priority packet. The number of service classes depends on the network protocol field size (ToS – Type of Service).

This queue management mechanism encourages the channel monopolization by a higher priority queue which increases excessively the end-to-end delay of the lower priority packets. The size of the queues is important to limit this phenomenon.

Another queue management mechanism used in WAN is CQ (Custom Queuing) which solves the disadvantages of FIFO and PQ mechanisms.

Similarly to PQ, CQ mechanism forwards the packets to different queues according to their class of service. Then, these queues have different assigned weights which correspond to the allocated transmission bandwidth (Fig. 4). This mechanism offers guaranteed bandwidth for all the classes of service, even for the lowest priority class currently named Best Effort (BE).

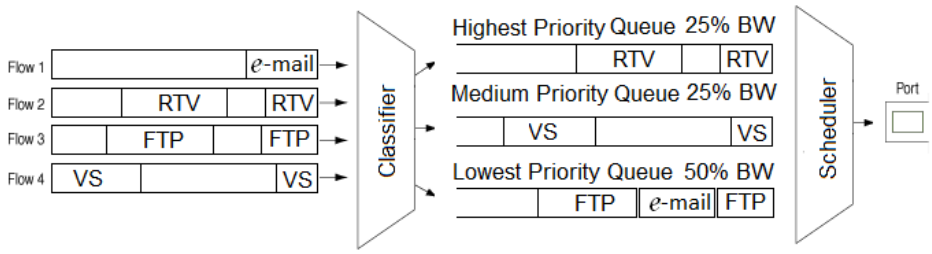

Fig. 4 – CQ Mechanism.

These mechanisms are not really related to the QoS and congestion occurs when all the packets have the same priority.

Videoconferencing service is disfavoured by all the presented queue management mechanisms. When the bandwidth requests overrun the available channel capacity, the transmission delay, the congestion risk and the packet loss rate are all increased and the QoS is seriously affected.

A simple simulation of these mechanisms (FIFO, PQ, CQ) using the OPNET network analyzer program (IT Guru Academic Edition 9.1) is made.

A videoconferencing scenario with four pairs of client–server nodes and an E1 communication channel is considered (Fig.5).

Image frames with 4,000 Bytes and 30 fps (frames-per-second) are transmitted simultaneously by all the clients.

The communication channel has only a capacity of 2,048 kbps so its capacity is exceeded by the videoconferencing traffic.

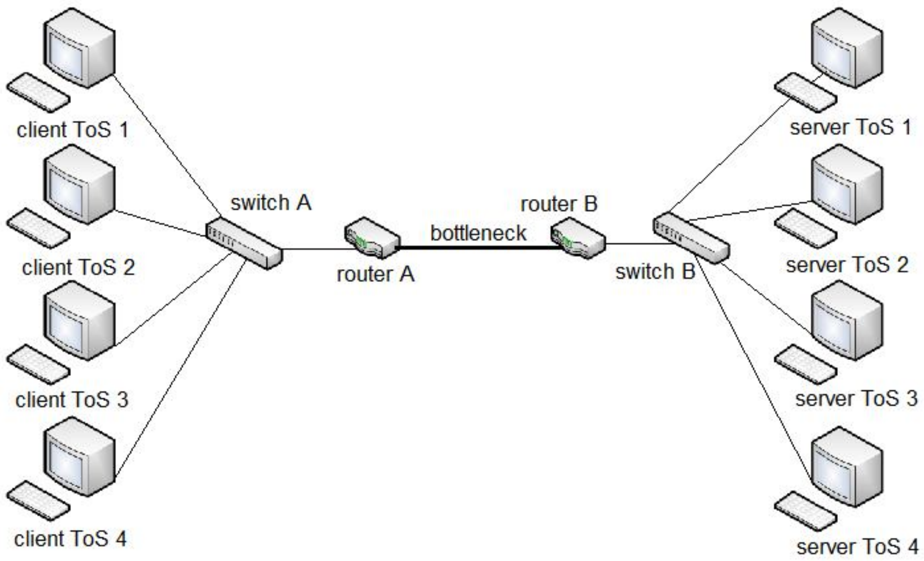

Fig. 5 – OPNET scenario.

Four ToS values are used for different service classes:

a) ToS 1 – Video Conferencing (streaming traffic);

b) ToS 2 – Video Conferencing (excellent effort traffic);

c) ToS 3 – Video Conferencing (standard traffic);

d) ToS 4 – Video Conferencing (background traffic).

Two transmission parameters are plotted for 150 seconds with an offset time of 10 sec. (Figs. 6 and 7).

Even if all the nodes have a transmission rate of 960,000 bps, the received traffic depends on the queue management mechanism used namely

a) 512 kbytes/sec. down to 15 bytes/sec. (decreasing towards the end of the simulation because congestion occurs at 25 sec.) using FIFO;

b) 510,000 bytes/sec. up to 490,000 bytes/sec. (decreasing towards the end of the simulation) using PQ;

c) 390,000 bytes/sec. (slightly variable during the simulation) using CQ.

The maximum loss rate is computed for each mechanism:

a) FIFO: 98.43%;

b) PQ: 46.67%;

c) CQ: 59.37%.

So, the most advantageous queue management method, regarding the maximum received traffic and the minimum packet loss rate, results to be PQ followed by CQ. Both methods avoid congestion and reduce the packet loss rate in comparison to FIFO.

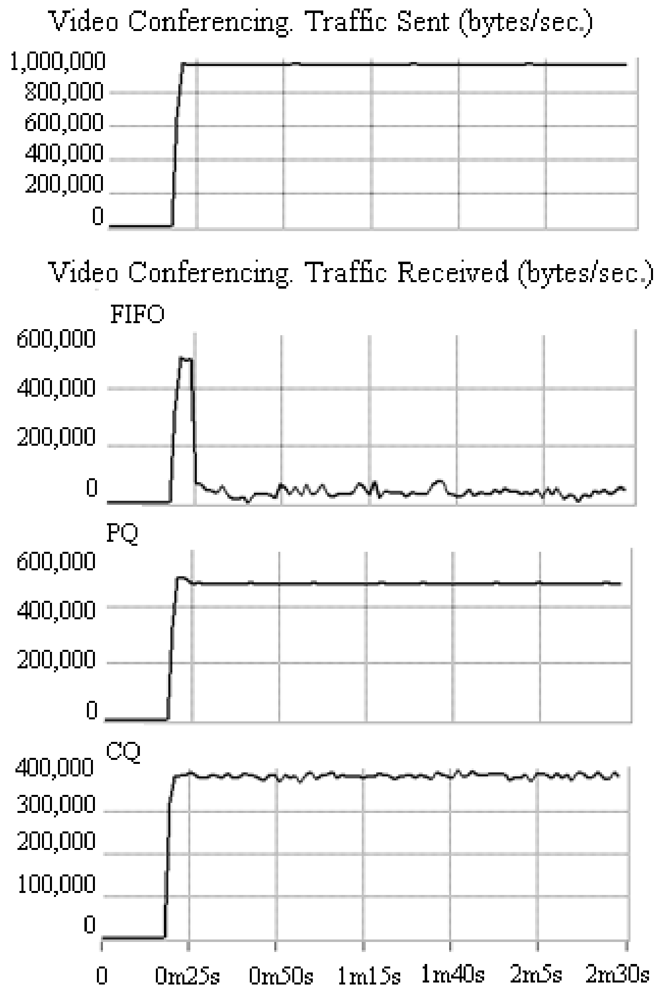

Fig. 6 – Comparison FIFO-PQ-CQ regarding the traffic received.

Regarding the end-to-end delay, it is higher with FIFO from 361 millisec. up to 2.89 sec. (increasing towards the end of the simulation), medium for CQ (increasing from 187 millisec. up to 323 millisec. towards the end of the simulation) and lower for PQ (ranging from 159 millisec. down to 33 millisec., slowly decreasing towards the end of the simulation).

In conclusion, PQ is the most performing queue management method for delay-sensitive network applications. Still it does not avoid congestion and packet loss.

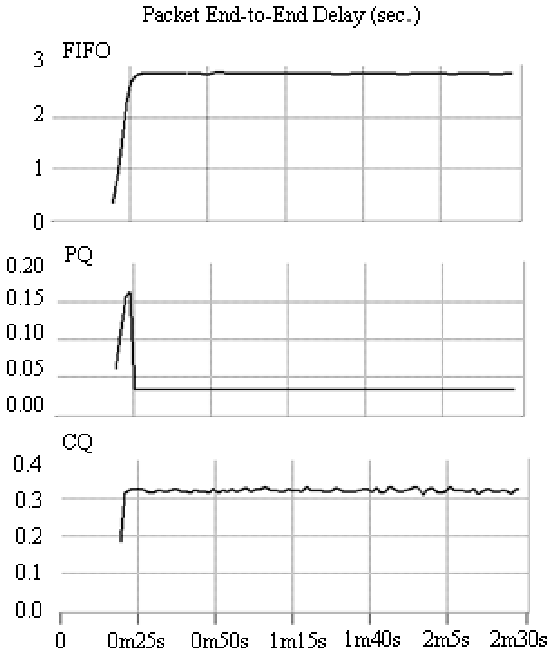

Fig. 7 – Global Packet End-to-End Delay.

3. Dynamic Priority Queuing with Congestion Control

The previous comparison of the queue management methods (FIFO, PQ and CQ) was made considering the same image resolution for all the clients whatever the transmission priority was and very high packet loss rates result from simulation.

A new queue management method with source notification for reducing the image resolution and video number of frame per second is proposed.

This method dynamically allocates the channel bandwidth to the nodes with the same kind of traffic (videoconferencing) depending their priorities and class of service. So the QoS of the same network service depends on the node priority.

The proposed queue management method is called *Dynamic Priority Queuing with Congestion Control* (DPQCC).

A notification must be sent to all the nodes when the packet loss rate is high (above a specified value).

These nodes must reconsider the transmission rate and reduce the throughput when the congestion risk is increased.

Each transmission node has to adapt its throughput to an available bandwidth, recommended by a monitor station.

For example, in the previous scenario, the first node has the highest priority and its transmission rate (960 kbps) is lower than the channel capacity (2,048 kbps). So, it can maintain the same video parameters (4,000 Bytes/frame and 30 fps).

The second node has an available bandwidth of 1,188 kbps so even its priority is lower, it can send with the same rate (4,000 Bytes/frame and 30 fps) and the same video quality.

The third node has an available bandwidth of 228 kbps so it has to reduce the video transmission rate. This can be done by decreasing the frame size to 1,296 bytes and the frame rate to 15 fps. Its transmission rate is reduced from 960 kbps to 162 kbps.

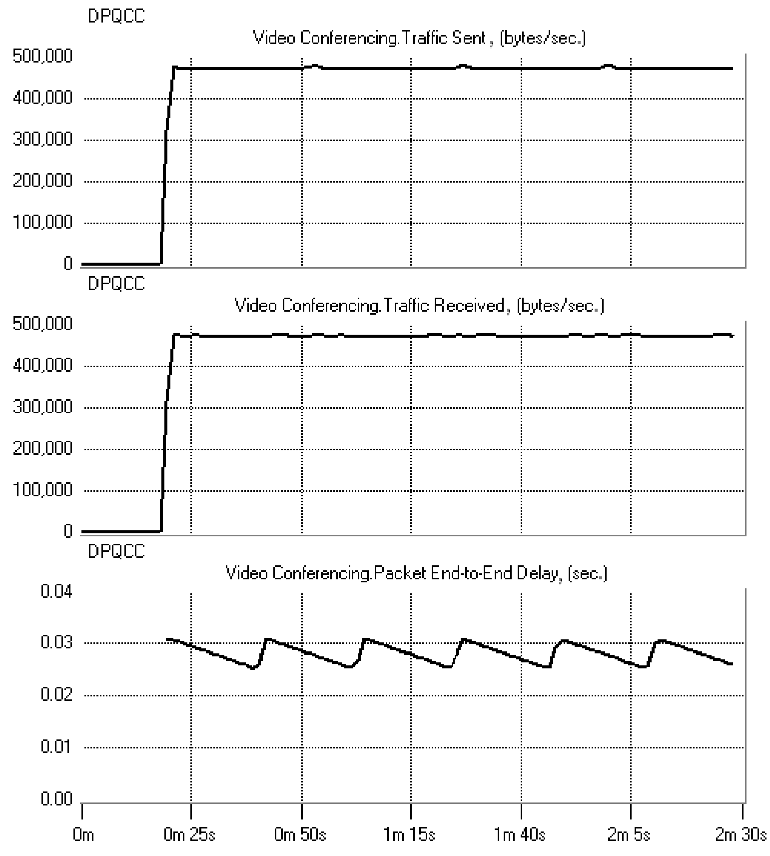

Fig. 8 – DQPCC Parameters.

The last node has an available bandwidth of about 66 kbps which is not enough for video transmission. The source is notified to transmit only voice (64 kbps) until reconsidering the available bandwidth.

This scenario solves the congestion problem and minimizes the packet loss rate. The overall QoS is increased, especially for the nodes with high priorities.

The simulation results for the new method are presented in Fig. 8.

No congestion and no packet loss occur. The packet end-to-end delay average value is about 28 millisec.

5. Conclusions

The queue management methods currently used (FIFO, PQ and CQ) do not differentiate the image quality for different transmission priorities, even if the packets are included in different classes of service. Simulations are made to illustrate their performances and PQ seems to offer the lowest packet loss rate and end-to-end delay for videoconferencing service. Still, the packet loss rate is high and congestion occurs. So, another mechanism is proposed for queue management and congestion control, DPQCC, which notifies the nodes about congestion imminence in order to reduce the video parameters according to the available bandwidth. Simulation results for this method confirm the theory.

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STUDIU COMPARATIV AL UNOR METODE DE GESTIUNE A COZILOR DE TRANSMISIE PENTRU CONTROLUL CONGESTIEI ÎN REȚELELE DE ARIE LARGĂ

(Rezumat)

Se prezintă un studiu comparativ care include trei metode de management al cozilor de pachete folosite în rețelele de arie largă. Performanțele acestor metode sunt ilustrate prin simulare, folosind programul OPNET. După analiza performanțelor

acestor trei metode, pentru serviciul de video conferinţă, se propune o nouă metodă de management al cozilor, cu adaptarea dinamică a parametrilor transmisiei video, în funcţie de lăţimea de bandă disponibilă, având ca scop controlul congestiei şi corelarea calităţii serviciului cu prioritatea fiecărui nod din reţea. Rezultatele simulării confirmă eficienţa metodei propuse.