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CONGESTION MANAGEMENT METHODS PERFORMANCES COMPARISON IN INTERCONNECTED WLANS FOR QUALITY OF SERVICE PROVISIONING

BY

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Abstract. Congestion management tools are key components of Quality of Service (QoS). Interfaces have to manage congestions due to bottleneck links between network devices, by activating queuing and scheduling mechanisms. Emptying the queues in such a manner to differentiate the packet forwarding, applications QoS requirements could be fulfilled. In interconnected IEEE 802.11 wireless LANs (WLANs) it is highly required to combine WLAN QoS and Internet Protocol (IP) QoS. We investigate the performances of IEEE 802.11e Medium Access Control (MAC) Enhanced Distributed Channel Access (EDCA) mechanism implemented in radio downstream/upstream, combined with different queuing and scheduling algorithms for congestion management in wired links between WLANs. Four types of traffic were considered, one for each EDCA Access Category (AC).

Key words: congestion; queuing; scheduling; QoS; WLAN.

1. Introduction

Multiple users are utilizing different network services, such as voice over IP (VoIP), video conferencing, file transfer, web browsing or *e*-mail, with

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different QoS requirements. Therefore, congestion is more likely to occur, given that some links between different devices or subnets could behave like potential bottlenecks. An optimal congestion management method has to be used in order to allow the network to run at full capacity, and to provide the required QoS to its users. A method to provide QoS and congestion control is to involve core mechanisms, like buffering, queue management, and scheduling, operating in network switching nodes such as routers, firewalls, switches.

WLANs are highly adopted because of theirs mobility advantages. In this paper we investigate a combination of WLAN QoS and IP QoS. We consider MAC EDCA mechanism for wireless subnets, traffic packets with different type of service (ToS), and various queuing and scheduling methods, such as First-In First-Out (FIFO), Priority Queuing (PQ), Weighted Fair Queuing (WFQ), and Custom Queuing (CQ), designed for use in network switching nodes. The performances of these algorithms are compared using global and local parameters such as traffic sent, traffic received, and end-to-end delay.

2. Background

MAC EDCA mechanism was introduced in IEEE 802.11e standard, which provides enhancements for QoS in WLAN, in both wireless stations and access point. Service differentiation is implemented through traffic handling in four FIFO queues, denoted as ACs: AC0 (for ToS = 1 and 2 packets), AC1 (for ToS = 0 and 3 packets), AC2 (for ToS = 4 and 5 packets), and AC3 (for ToS = 6 and 7 packets). Each AC behaves like a virtual station and contends for access to the medium. The purpose of using different contention parameters for different ACs is to give a low-priority class a longer waiting time than a high-priority class, so the high-priority class is likely to access the medium earlier than the low-priority class (3 being the higher priority, and 0 the lower one).

In FIFO, all incoming packets are placed in a single queue and they are served in the same order as they were received. Packet delay is a direct function of the size of the FIFO queue, but there are many undesirable properties. Since all packets are inserted into the same queue, it is impossible to offer different services for different packet classes. When an incoming flow suddenly becomes bursty, then it is possible for the entire buffer space to be filled by this single flow and other flows will not be served until the buffer is emptied.

PQ offers differentiated services to different classes of packets. Each incoming packet is classified into different priorities and it is placed into separate queues accordingly. Packets of higher priority are transmitted before lower ones. As shortcomings, if there is a large continuous flow of high priority traffic into the queue, then low priority packets will experience excessive delay, or even service starvation.

Fair Queuing (FQ) allows fair access for each incoming flow and prevents a bursty flow from consuming all of the output bandwidth. FQ contains a queue for each distinct flow and packets from each flow are inserted into its respective queue. The system serves each queue one packet at a time in a round-robin fashion. WFQ is a variation of FQ since it supports flows with different bandwidth requirements, by assigning each queue with different weights that correspond to the proportion of the allocated output bandwidth. In WFQ, each incoming packet is time stamped with a finish time in addition to being placed into its corresponding flow queue. Selection of which packet to be served is made based on finish times, thus ones with earlier finish times are transmitted before later ones. It is possible, for a later packet, to have a finish time stamp that is smaller than an earlier packet.

In CQ each packet is classified as belonging to a particular service class and is placed in the queue for that class. Each service class is assigned a weight that corresponds to the percentage of the output bandwidth allocated to it. Packets from each queue are transmitted based on the weight assigned to their queues.

3. Simulation and Results

3.1. Simulation Model

We use the network simulator OPNET Modeler to evaluate the performance of the network model. This model consists of two IEEE 802.11e WLANs with EDCA mechanism for MAC sublayer, each including four wireless workstations (QSTAs) with no mobility, and a fixed access point (QAP). We choose 802.11b parameters for the PHY layer, and the data rate is set to 11 Mb/s. Clients from one subnet communicate with clients from the other subnet. Four pairs of clients were defined, each one handling different ToS based traffic, belonging to four different ACs: interactive voice (ToS = 6, AC3), streaming multimedia (ToS = 4, AC2), excellent effort (ToS = 3, AC1), and standard (ToS = 2, AC0). For comparison reasons it was assumed that each AC has 25% of the total data traffic, the same packet rate and the same packet size. The two subnets are connected *via* two routers through a wired link, representing a potential bottleneck. This model is simulated with four different scenarios, comparing various queuing and scheduling techniques: FIFO, PQ, WFQ, CQ and WFQ. Applications start time was set to 100 s, and the simulation stop time was set to 150 s.

3.2. Simulation Results and Performance Comparison

According to Fig. 1 *a* the global (bidirectional) traffic sent is the same in each scenario (600 kbytes/s = 2 ways × 4 workstations × 75 kbytes/s).

From Fig. 1 *b* the highest global traffic received is obtained for WFQ scenario (around 500 kbytes/s), followed by PQ (around 450 kbytes/s), CQ (around 420 kbytes/s) and FIFO (around 500 kbytes/s, followed by 250 kbytes/s).

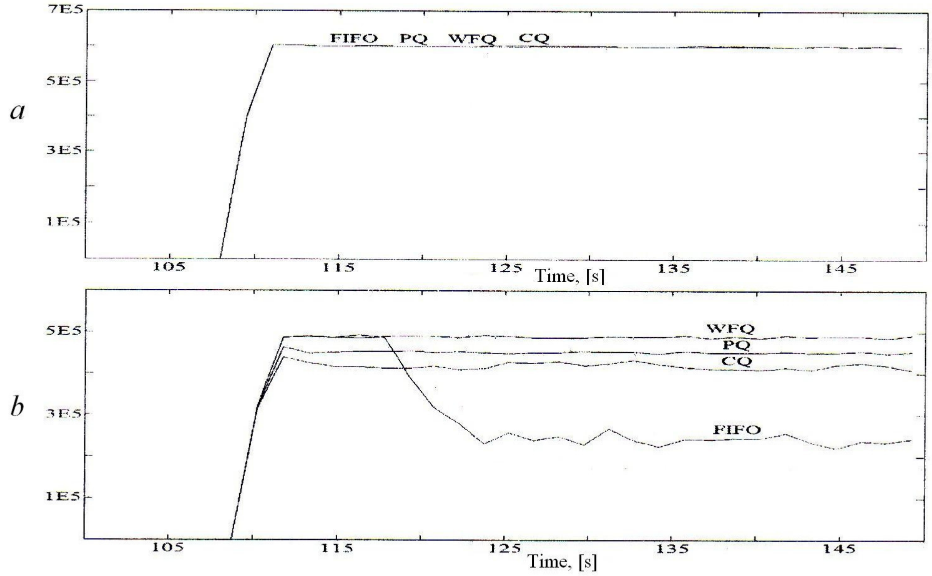

Fig. 1 – *a* – Global traffic sent, [bytes/s]; *b* – global traffic received, [bytes/s].

According to Fig. 2 *a*, PQ, WFQ and CQ scenarios allow almost the same rate in local (unidirectional) ToS = 6 traffic received as in local ToS = 6 traffic sent (75 kbytes/s), but FIFO fails.

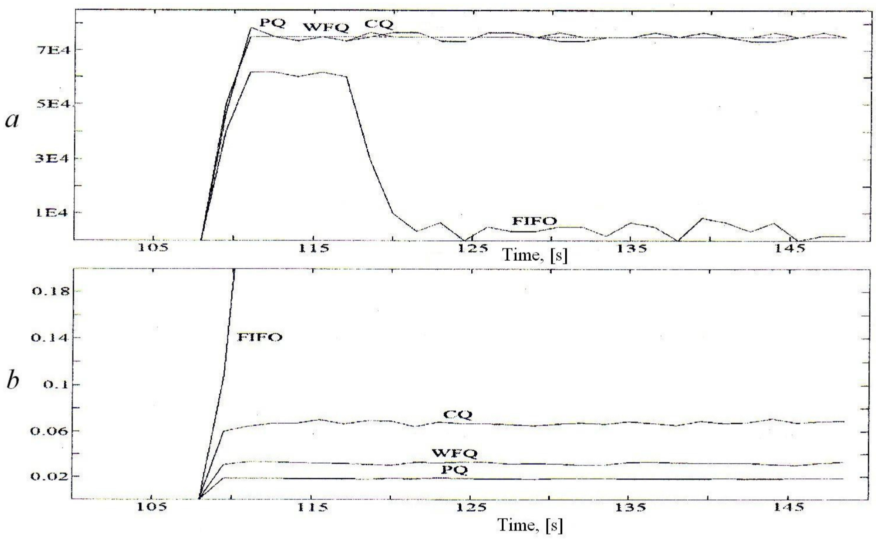

Fig. 2 – *a* – Local ToS = 6 traffic received, [bytes/s]; *b* – local ToS = 6 packet end-to-end delay, [s].

Comparing local ToS = 6 packet end-to-end delay from Fig. 2 *b*, PQ, WFQ, and CQ scenarios allow small values (0.018 s, 0.032 s, and 0.068 s, respectively), which in addition to the previous remark, make them suitable for VoIP application. FIFO fails with around 2 s ToS = 6 packet end-to-end delay.

According to Fig. 3, PQ and WFQ scenarios allow almost the same rate in local ToS = 4 traffic received as in local ToS = 4 traffic sent (75 kbytes/s). FIFO and CQ require packet dropped retransmissions.

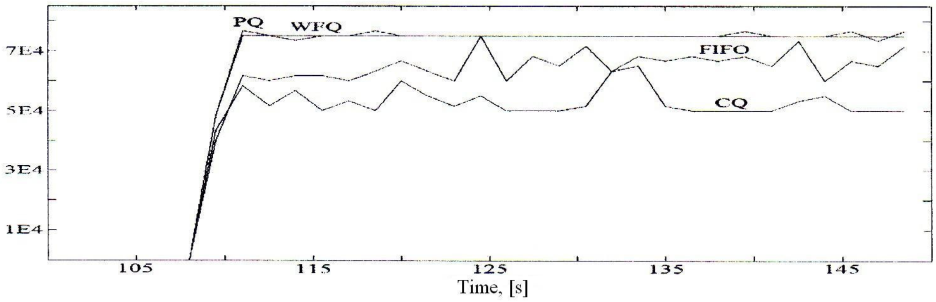

Fig. 3 – Local ToS = 4 traffic received, [bytes/s].

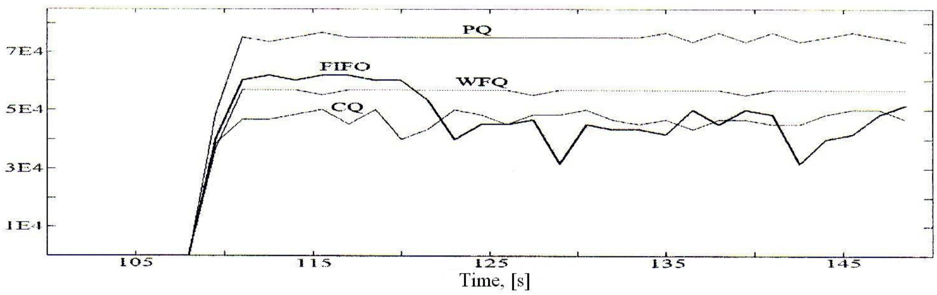

Fig. 4 – Local ToS = 3 traffic received, [bytes/s].

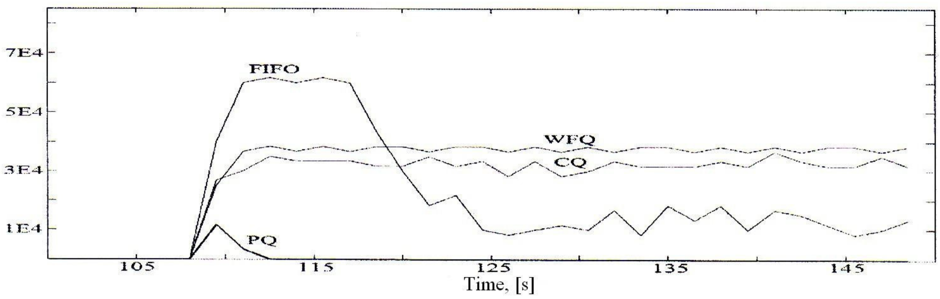

Fig. 5 – Local ToS = 2 traffic received, [bytes/s].

According to Fig. 4, PQ scenario allows the same rate in local ToS = 3 traffic received as in local ToS = 3 traffic sent (75 kbytes/s), followed by WFQ (around 56 kbytes/s, *i.e.*, 75% of traffic sent), CQ and FIFO. For this type of traffic, packet dropped retransmissions are allowed in some limits, so WFQ is a challenger for PQ.

According to Fig. 5, none scenario allows the same rate in local ToS = = 2 received as in local ToS = 2 traffic sent (75 kbytes/s). For this type of traffic, packet dropped retransmissions are allowed in larger limits, so WFQ (around 38 kbytes/s, *i.e.*, 51% of traffic sent), or even CQ could be acceptable options, but FIFO and PQ fails.

4. Conclusion

The queuing and scheduling algorithms such as FIFO, PQ, WFQ and CQ, are tradeoffs between complexity and fairness, each one having its own benefits and limitations, and the best one depends on the current traffic flow and network conditions. Based on simulations, with four scenarios with different kind of traffic, we observed that FIFO fails in most of the cases in comparison with the others. Based on the simulation results, in wired link interconnected WLANs serving clients with different QoS requirements, WFQ queuing is the best choice, especially when packet retransmissions are allowed for lower priority traffic.

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PERFORMANȚE COMPARATIVE ALE METODELOR DE MANAGEMENT AL CONGESTIEI ÎN REȚELE WLAN INTERCONECTATE PENTRU ASIGURAREA CALITĂȚII SERVICIILOR

(Rezumat)

Instrumentele de management al congestiei sunt componente cheie ale calității serviciilor în rețelele de comunicații. Interfețele trebuie să gestioneze congestiile, activând mecanisme de plasare a pachetelor în cozi de aşteptare şi de deservire a lor. Cerințele de calitate pot fi îndeplinite dacă înaintarea pachetelor se face diferențiat. În rețelele WLAN 802.11 se recomandă combinarea calității serviciilor WLAN cu cele ale protocolului Internet. Se investighează performanțele mecanismului EDCA, combinat cu algoritmii FIFO, PQ, WFQ şi CQ, pentru patru tipuri de trafic.