QoS IN IEEE 802.11 WIRELESS LAN: CURRENT RESEARCH ACTIVITIES

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Abstract

The IEEE 802.11 wireless LAN (WLAN) is the most widely used standard nowadays for wireless LAN technology. However, the current standard does not provide QoS support required by the wide range of end applications. Thus, a large number of enhancements to the standard are being proposed. This paper presents a survey of the on-going research activities. We also overview the upcoming IEEE 802.11e standard being introduced. The IEEE 802.11e standard is a proposal defining the mechanisms for wireless LANs aiming to provide QoS support to bandwidth-sensitive applications such as voice and video communications.

Keywords: *IEEE 802.11, QoS, IEEE 802.11e*

1. INTRODUCTION

Nowadays, the use of WLANs is on the increase mainly due to their low cost, their ease of deployment and, above all, by allowing the end users to freely move around within the area they cover [1]. Another influential factor is the appearance in 1997 of the standard IEEE 802.11, with its subsequent revision in 1999 [2], and its subsequent amendments that nowadays enables transmission speeds of up to 54 Mbps.

The basic access function in IEEE 802.11 is the *Distributed Coordination Function* (DCF) where before transmitting, a station, the source station, must determine the state of the channel. If during an interval of time, called *Distributed InterFrame Space* (DIFS), the channel is sensed free, the station can initiate its transmission. If the channel is sensed busy, once the transmission in progress is finished and to avoid the collision with other stations in the same situation, a backoff algorithm is initiated. This algorithm consists in choosing an interval of time (the *backoff time*) at random during which the station delays the transmission of its frames. Once having transmitted the source station, it will wait to get back a reply from the destination station. If after waiting for a time interval, denominated *Short InterFrame Space* (SIFS<DIFS), the source station does not get the *Immediate Positive Acknowledgement* (ACK) from the destination station, it simply assumes that there has been a collision. The source station can then attempt to retransmit a finite number of times using a longer backoff time after each attempt. This access function is easy to implement and suitable for most applications. However, it does not provide Quality of Service (QoS) support.

As an alternative but optional solution the *Point Coordination Function* (PCF) can in turn be used. It is a centralized access method where a node, the *Point Coordinator* (PC), will poll in turn each one of the stations allowing them to transmit without having them to compete with each other in order to gain access to the channel. This method is only used during *Contention Free Periods* (CFP) started at regular intervals by the PC. The PCF mode has been designed to give QoS support but it is limited by the polling scheme being used [3] and by the fact that the beginning of the CFPs is random. This randomness can delay the transmissions from the polled stations adding an extra access delay [4].

The above open issues have led many researchers to design techniques to provide solutions for both operation modes, DCF and PCF, using traffic engineering principles [5], with the objective of making a better use of the network resources. In this work, we overviewed and classified a large number of the proposed techniques. We also review the ongoing efforts towards the definition of the IEEE 802.11e standard for wireless local networks with QoS support.

2. QoS IN IEEE 802.11

As shown in Figure 1 we have reviewed 27 techniques. Previous survey papers have presented a reduced number of QoS-aware techniques based on the IEEE 802.11 standard [6]. Some other studies have only focused on the DCF technique [7].

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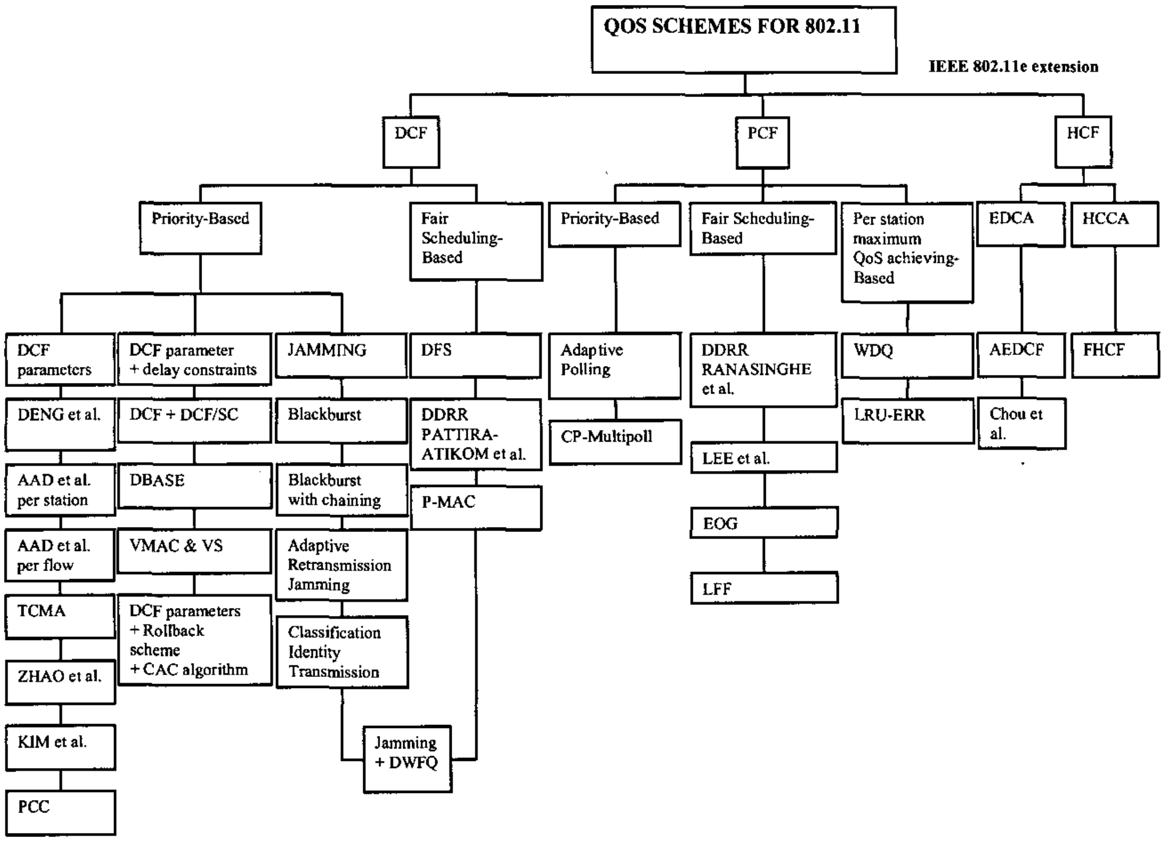

Figure 1.- QoS mechanisms in WLANs IEEE 802.11

Each technique is focused on modifying one of the coordination functions. First we distinguish between those techniques affecting the DCF and PCF. Various approaches have been used for both of them: the first approach is based on priorities, giving access preference to those stations that have been assigned higher priority. The second approach uses fair scheduling algorithms and shares the resources proportionally to a pre-assigned weight. Finally, a third approach (only in PCF) is based on maximizing the amount of flows whose QoS needs are covered.

2.1 QoS support for DCF

2.1.1 Priority-based. In some techniques, the assignment of the priorities that allow preferential access to the channel, is done by assigning different values to the parameters used to access the medium: the IFSs and the CWs. Due to the characteristics of the DCF, the shorter the IFS used, the earlier a flow will be able to start transmitting. However, a shorter CW translates into a shorter backoff time. This is true in the schemes by **Deng et al.** [8], **Kim et al.** [12] and **Aad et al.** [9], where these assignments are for a finite number of priority classes. This is also used in the priority scheme by **Zhao et al.** [11] where the assignment is done in a dynamic way to maximize the throughput of the system. **Chen et al.** in [13] shows the **Priority-based Contention Control** (PCC) scheme where the calculation of the CW depends on the Priority Limit (PL) (sent in each transmission) which is the value used to forbid the access to the channel by those stations with less priority. Besides these two parameters, some other authors have used different factors to control the exponential increase of CW when there are collisions. This is the case of the **TCMA (Tiered Contention Multiple Access)** protocol [10] and one of the schemes by **Aad et al.** [9]. The latter also introduced a differentiation mechanism based on the frame sizes. It is worth pointing out one of their studies which shows that the use of TCP traffic decreases the difference between the priority types. That is the main reason why they suggest using flow rather than station based mechanisms.

However, the authors in [14] have shown that although the use of these parameters can be used to handle multiple priority levels, they are not appropriate to limit the frame delay. Therefore, some authors have integrated extra controls into their mechanisms to address this issue. This is the case of algorithms **Virtual MAC and Virtual Source (VMAC and VS)** [15]-[16] that emulate the operation of the MAC and application layers in order to obtain reliable statistics for all types of QoS measures, used by an admission control mechanism. On the other hand, the **DBASE (Distributed Bandwidth Allocation/Sharing/Extension)** protocol [17] uses different IFS for asynchronous and real time traffic where the former must use DCF and the latter can keep, share and free the resources in a dynamic way. Regarding the **DCF + DCF/SC** scheme [18], the higher priority traffic uses the **Distributed Coordination Function with Short Contention-window** (DCF/SC), with a smaller CW and a time SIFS<DIFS. Finally, **Chen et al.** [19] add an algorithm of admission control, the **Connection Admission Control** (CAC) that bases its decisions on the available resources.

Another way to establish priorities consists in substituting the backoff algorithm by the transmission of a jamming signal. In this case, since a station has to be inactive when it detects a signal in the channel, that which produces a longer-length jamming signal is assured of getting the channel.

This is the technique used by the **BlackBurst** scheme [20] where the jamming signal is proportional to the time the station is forced to wait. In [21] a process is added to this scheme to maximize the amount of data to be sent per frame, and a chaining mechanism is also added to invite stations to transmit so that the waiting time is shortened between two consecutive transmission. In the **Jamming-Based Retransmission Mechanism**, Chen et al. suggest an effective and adaptable retransmission mechanism that can limit the delay and the jitter of the frames using a jamming signal whose length depends on the amount of stations and the length of their frames. And finally, **Sheu et al.** [23] introduce a distributed scheme where those stations that have transmitted the bigger jamming signal proportional to their priority would send their frames in order according to the ID that they have been assigned.

2.1.2 Fair Scheduling-based. The schemes which are based on the assignment of priorities do not work well if the number of stations is large. The solution consists of using fair scheduling algorithms. In these cases well known algorithms which have given good results applied to their equivalent wired networks are usually used.

The **Distributed Fair Scheduling** (DFS) algorithm [24] integrates within DCF the Self Clocked Fair Queuing (SCFQ) algorithm which selects a frame to transmit and uses a mapping scheme to calculate the backoff time proportional to its size and to the assigned weight. The **Distributed Deficit Round Robin** scheme [25], presented by Pattira-Atikom et al., eliminates the backoff time and is based on a Deficit Round Robin (DDR) algorithm which assigns an IFS proportional to the Deficit Counter (DC) whose magnitude is employed to obtain permission to send frames. And the **Priority Based Fair MAC** protocol (P-MAC) [26] adjusts the CWs basing itself on the *Bianchi's* paper [27] so that each station starts transmitting at the optimum time thus minimizing collisions.

The last technique in this section presented by **Banchs et al.** [28] is a special case because it uses, depending on the type of traffic involved in transmission, a priority scheme based on the jamming or on the Distributed Weight Fair Queuing (DWFQ) algorithm which assigns dynamically a CW based on a variable consistent with the traffic transmitted and with the weight assigned and which must be the same for all.

2.2 QoS support for PCF

It is possible that by making the use of PCF optional has had an influence in that the majority of the proposals have been for DCF. The principal objective of the techniques for PCF is to obtain the polling mechanism which meets the QoS needs of traffic.

2.2.1 Priority-based. The **Adaptive Polling Algorithm** [29] is based on assigning higher priority to those stations which have responded to polling more times, calculated with the help of the Additive Increase/Multiplicative Decrease (AIMD) algorithm. The **Contention Period Multipoll** (CP-Multipoll) mechanism aspires to incorporate the DCF access scheme into the planning of polling in PCF [30]. The idea is that the PC can periodically poll various stations at the same time assigning each of them different backoff times, that being less for higher priority stations.

2.2.2 Fair Scheduling-based. In the **Distributed Deficit Round Robin** (DDRR) [31], Ranasinghe et al. propose that the PC should use polling based on the Deficit Round Robin (DRR) algorithm. The stations which the PC polls must have a positive Deficit Counter (DC) which increases according to the weight assigned. Another scheme is that of **Lee et al.** [32] which applies an admission control which respects the maximum delays of the real time traffic (using the Earliest Due Date algorithm – EDD) and the needs of throughput of the non-real time traffic. The planning schemes of **Adamou et al.** aim at maximizing the system's transmission rate minimizing the rate of discard. In [33] the **EOG** scheme is presented which gives priority first to those stations with frames which are about to be discarded (as in Earliest Due Date - EDD) and then to those which have had the highest discard rate (as in Greatest Loss first – GLF). The same authors also present another scheme called **Lagging Flow First** (LFF) [34] which favours the transmission of those frames which belonging to a given flow with a discard rate above the admission rate.

2.2.3 Per station maximum QoS achieving-based. In [35] it is suggested that fairness is not necessarily the best solution. Better results can be obtained by trying to maximize the number of stations whose QoS needs are covered sacrificing only a minimum number of the stations. Ranasinghe et al. in [36] present two alternatives. In the first called **Embedded Round Robin** (ERR), the PC maintains two polling lists, one with those stations which have frames for sending and the other with those that do not have. In each turn all those from the first list can transmit and only one from the second is polled so that it can inform as to whether or not it now has any frame to transmit. When there is congestion this scheme does not work well. As a solution they offer this second technique, the **Wireless Dual Queue** (WDQ), which adds the Dual Queue (DQ) algorithm to the ERR and consists in temporarily setting aside those station which load the network at times of congestion. In [37] a third technique is presented called **Least-Recently-Used ERR** (LRU-ERR), also based on the ERR scheme, which limits the introduction of stations in the first list when there is congestion.

3. THE FUTURE IEEE 802.11e STANDARD

At the same time, the IEEE 802.11 task group E is working on the introduction of mechanisms which give QoS support. The description of these mechanisms, which are presented below, is based on the unapproved IEEE 802.11e/Draft 6.0 [38] of November 2003.

In IEEE 802.11e a third function of coordination is added to DCF and PCF: the Hybrid Coordination Function (HCF). This new coordination function is obligatory for all stations and incorporates two new access mechanisms: the Enhanced Distributed Channel Access (EDCA) known in previous drafts as Enhanced DCF (EDCF) which, as its name suggests, sought to substitute DCF; and HCF Controlled Channel Access (HCCA), known in previous drafts as HCF.

31 Enhanced Distributed Channel Access (EDCA)

In this mechanism each station enables four *Access Categories* (AC) to which one of the eight levels of priority defined in IEEE 802.11e are assigned. Each AC forms an independent EDCA entity with its queue and its DCF access function with its *Arbitration InterFrame Space* (AIFS[AC]) and its contention window ($CW_{min}[AC] \leq CW[AC] \leq CW_{max}[AC]$). The use of different queues can lead to an internal collision which is resolved by giving access to the channel with higher priority (the others have to proceed as for an external collision).That queue which succeeds in getting the channel obtains a *Transmission Opportunity* (TXOP). Each TXOP has a limited duration during which an AC can send the frames it wants.

As has happened with DCF, various researchers have brought improvements to EDCA. The **Adaptive EDCF** scheme (AEDCF – based on draft 3.1) [39] proposes to vary the CW of each queue depending on the amount of collisions suffered, using less magnified factors for the ACs which have higher priority. The priority scheme of **Chou et al.** (based on draft 3.0) [40] presents an algorithm for the calculation of the AIFs able to increase the total throughput of the system and a common small CW to minimize the periods of inactivity.

3.2 HCF Controlled Channel Access (HCCA)

As in PCF, in the HCCA mechanism a central node is used which coordinates access to the medium, the *Hybrid Coordinator* (HC). The difference is in that the HC can act at any time polling the stations which have previously made a request for a TXOP. The planning of the polls and the implementation of admission controls are not made compulsory by IEEE 802.11e although in appendix H of the draft there is an informative example of each of them.

This non imposition has allowed an alternative scheme to be presented, the **FHCF** scheme (based on draft 4.1) [41]. IEEE 802.11e is efficient with CBR traffic but not with VBR, thus the authors are presenting new algorithm designed to support the two guaranteeing the minimum *Service Interval* (SI – represents the time interval between two consecutive pollings).

4. CONCLUSIONS

It is evident that the boom in multimedia applications has pushed many researchers to include differentiation and QoS support techniques to WLAN based on the standard IEEE 802.11. In this work we have presented and classified 27 techniques grouped according to their modified coordination function. We have also seen that on the meantime, the IEEE 802.11 task group E is working on the definition of the IEEE 802.11e standard, an amendment which endeavours to include access mechanisms which allow the QoS needs of WLAN traffic to be taken into account. Although it is still at the stage of a draft standard, several studies have already been conducted aiming to verify the proposed amendments.

As a future project we intend to make an quantitative comparison among all the proposed techniques based on our classification. We have not been able to use the evidence and evaluations carried out by their authors due to the different configurations used in each case.

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