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I. Introduction

IEEE 802.11e is the draft of amendments introducing QoS (*Quality of Service*) to the IEEE 802.11 standard. 802.11e supports HCF (Hybrid Control Access) combining two Access modes: EDCA (*Enhanced Distributed Channel Access*) and HCCA (*HCF Controlled Channel Access*). EDCA is a distributed channel access function enabling prioritization. In this paper we will discuss problems inherent to collision management within EDCA. The paper organizes as follows : the first part will present the Enhanced Distributed Channel Access. Then we will expose the issue of collision management. In the third part we will detail our proposal for a modification of the EDCA's collision management. The final part will conclude the paper. For concision sake, the protocols will not be detailed. Readers who are unfamiliar with the subject are invited to refer to [2] and [1] for further details.

II. EDCA

A. Access Function

The access function used by EDCA is CSMA/CA (Carrier Sense Medium Access with Collision Avoidance) [2]. The enhancements that EDCA brings to 802.11 DCF is introducing traffic priorities and hence having four queues with different priorities instead of a unique traffic queue. A prioritized queue is characterized by its Contention Window (CW) range (as in 802.11) and its specific Inter Frame Space (IFS), these elements determine the backoff procedure : making queues from a lower priority wait probabilistically more than those of higher priority before being able to access the medium. The queues (or Access Categories-AC) are baptized according to the applications that could use them. The AC in descending order of priority are : AC_VO (AC VOice), AC_VI (AC VIdeo), AC_BE (AC Best Effort) and AC_BK (AC BacKground).

B. Collision Management

In addition to the real collisions (physical collisions on the medium) that involve queues from two different stations, EDCA introduces a new kind of collisions : virtual collisions. Virtual collisions involve two queues belonging to the same station : if the backoff procedures of several (up to 4) different queues within the same station finish at the same time slot, the queue with highest priority will win the right to try to access the medium, the others will behave as if a real collision occurred (i.e. its contention window is doubled within the contention window range).

III. The problem of collision management

A. Prerequisites

In order to clearly expose the problem of collision management in EDCA, we first must define the different scenarios of collision within a station (figure 1) :

- $VC \circ RC$: Scenario taking place when a Virtual Collision (VC) occurs within a station followed by a Real Collision (RC) on the medium as in figure 1-a.
- $VC \circ \overline{RC}$: Scenario taking place when a Virtual Collision occurs within a station and no Real Collision ($\overline{RC}$) on the medium as in figure 1-b.
- $\overline{VC} \circ RC$: Scenario taking place when a Real Collision occurs on the medium that has not been preceded by a Virtual Collision ($\overline{VC}$) within the station as in figure 1-c.
- $\overline{VC} \circ \overline{RC}$: Scenario where no Collisions, whatsoever, occur. An AC of the station accesses the medium with no problem (not represented in figure 1) .

B. Problem description

Collision management's essential purpose is protecting and improving medium utilization. However, in the case of a virtual collision, this is not always true. Consider a station with both a AC_VO and a AC_VI queue. When both queues go into a virtual collision, AC_VI having the least priority will have its CW doubled, AC_VO will access the medium. If no real collisions occur (scenario $VC \circ \overline{RC}$), it is worthless to penalize the AC_VI queue (this would have no positive effect on medium utilization). In addition to the previous, EDCA's virtual collision management presents several problems. The first is a problem of priority inversion. AC_VI enduring virtual collisions may have its CW become bigger than that of an AC of lesser priority. The other problem is that of fairness. EDCA assigns to each priority a set of characteristics (range of CW, IFS) that should be the same for all queues of the same priority within one Basic Service Set (BSS). In doing this, EDCA supposes that all queues of the same priority should have an equal chance of access to the medium. Because of the way it handles virtual collisions in certain local contexts, equal chance of access is not achieved. We define a local context as the combination of arrival profiles of different queues within the station the queue is. Consider two stations in a BSS.

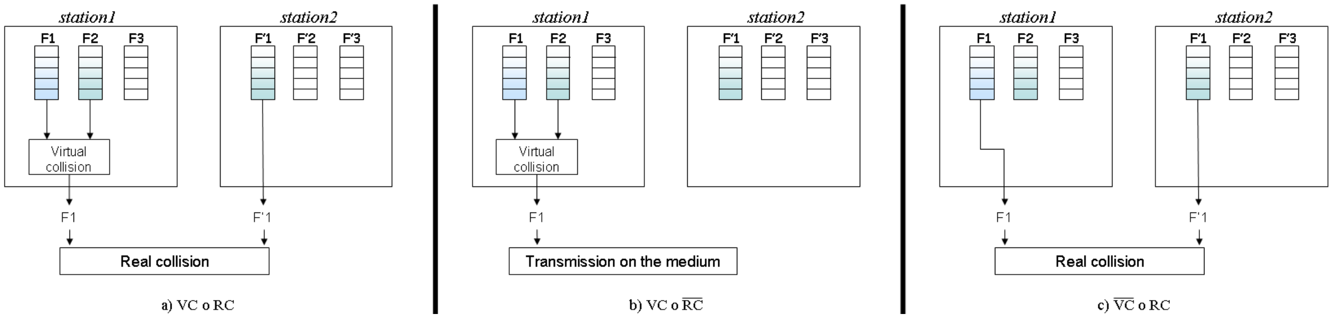

Fig. 1. Different possible scenarios $a)VC \circ RC$; $b)VC \circ \overline{RC}$; $c)\overline{VC} \circ RC$

The first, *station1* has its queues AC_VO and AC_VI being used. The second *station2* has its AC_VI queue used. Both AC_VI queues have the same arrival profile. However they are placed in different local contexts. To be *fair*, EDCA must give equal chance of access to the medium to both AC_VI queues. However simulations have been carried out proving EDCA's unfairness, *station2*'s AC_VI queue will have a better throughput despite having the same arrival profile. In such a situation, *station1*'s AC_VI is subject to virtual collision, this causes its contention window be greater than that of *station2*'s AC_VI.

IV. Solution proposal and discussion

A. Modification proposed

In order to resolve the problems in III-B a modification proposal is made. We describe it hereafter : *"Conditional_VC_Penalization"*. This modification is based on the following reasoning. The virtual collision management, as defined in 802.11e, justifies itself when having a lot of traffic (scenario $VC \circ RC$) : the extension of CW, after a VC, allows to lower the collision occurrence probability and thus to attain a better medium utilization. On the other hand, when several VC but no RC occur, that would mean the medium is not loaded. It seems interesting not to extend the CW: this way, we avoid both the priority inversion and the unfairness discussed earlier. We then propose to adopt the following behavior :

1) in case of a virtual collision not followed by a real collision (scenario $VC \circ \overline{RC}$), the ACs are not penalized.
2) in case of a virtual collision followed by a real collision (scenario $VC \circ RC$): are penalized both the collided ACs and the ACs that virtually collided within the collided station, thus respecting collision avoidance directives.
3) in all other cases, EDCA's behavior is respected.

When an AC is penalized, its Contention Window is doubled within the contention window range.
The behavior of this proposal should be thoroughly studied as per its fairness and the throughput it achieves.

B. Discussion

In this section, future work on EDCA and our proposal is discussed. Two main directions are outlined: the first is considering the protocols in permanent regime, the second direction will consider transitional regime.

a) Permanent regime: When applied, the modification we propose may solve the problems of fairness and utilization protection we expose in III-B. It is essential to study the modification in realistic scenarios. Doing so will enable us to recognize the scenarios among those in III-A that are frequent. If the scenario $VC \circ \overline{RC}$ is frequent, our modification will have several positive consequences as discussed in IV-A: avoid priority inversion within a station and guarantee virtually collided queues the throughput they would have attained without VC. In case the $\overline{VC} \circ \overline{RC}$ and $\overline{VC} \circ RC$ scenarios outnumber other scenarios, it may be useful to remove all virtual collision management. In this case, collided queues (on the medium) are the only ones to be penalized. This modification reduces the complexity of the protocol.

b) Transitional regime: We must keep in mind that, in case of real time applications, transitional behavior may be very critical. If, in a transitional regime, a queue has lesser throughput due to local context evolution, the application may endure serious prejudice. That is why, along with the large scale modeling of protocols, a more detailed, shorter scale modeling must be performed in order to cover all the aspects of the protocol and the proposals.

V. Conclusion

In this paper, we exposed the ongoing research being done on several aspects of IEEE 802.11e. We exposed the problem we encountered and a proposal to make up for them. We detail the future directions of work. Study of the protocol and the modifications is in progress essentially using modeling and simulation of the protocol.

Acknowledgment

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References

[1] IEEE Std. 802.11, *International Standard for Telecommunications and Information Exchange between Systems – LAN/MAN specific Requirements – Part 11: Wireless LAN MAC and PHY specifications*, 1999.

[2] IEEE Std. 802.11e/D 13.0, *Draft Supplement to Standard for Telecommunications and Information Exchange between Systems – LAN/MAN specific Requirements – Part 11: Wireless LAN MAC and PHY specifications – Amendment: Medium Access Control QoS Enhancements*, January 2005.