Enhancing IEEE 802.11e standard in congested environments

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ABSTRACT

IEEE 802.11e is a wireless local area networking standard introducing quality of service. It defines new MAC protocols, mainly HCF and EDCF. EDCF is a contention-based channel access scheme and is part of HCF for infrastructure networks and may be used as a separate coordination function for wireless ad-hoc networks. The aim of this paper is to propose a set of methods in order to enhance the QoS performances in the wireless local area network WLAN 802.11 in the congested environments under high traffic load. We adopt Slow Decrease scheme as static method and dynamic tuning of CWmin. We use simulations to show their performances to the legacy standard IEEE 802.11e, and then we compare the two approaches in high congested environments.

1. INTRODUCTION

The demand of multimedia applications has remarkably risen in last years. These ones require a certain quality of service as throughput, delay and jitter.
IEEE 802.11e is the enhancement of legacy standard which supports quality of service in WLAN. It introduces two new access methods to the medium, Hybrid Coordination channel access (HCCA) and the Enhanced Distributed Coordination Function (EDCF), renamed in latest 802.11e draft [2] to EDCA (enhanced distributed channel access).
EDCF is a contention-based channel access scheme. It is part of HCF for infrastructure networks and may be used as a separate coordination function for wireless ad-hoc networks. It provides service differentiation by defining 4 access category (AC). The standard supports 8 user priorities (UP) for traffic category, related to applications. They are associated for each AC [1].

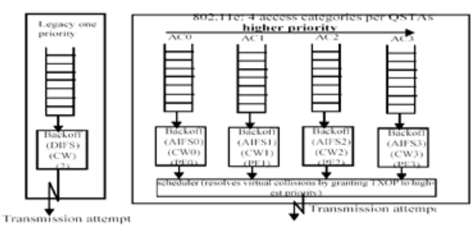


Figure 1. EDCF vs DCF

EDCF defines new parameters as AIFS (Arbitrary interframe space), number of time slots for each AC, CW [AC], many size of contention window for an AC. Thus, the CWmin and CWmax parameters can be set differently for different access categories, such as, a high priority AC with small values of CWmin and CWmax. After each unsuccessful transmission, the size of new CW[AC] for each access is calculated:

$$CW\,[AC\,] = 2 \times CW\,[AC\,] + 1 \qquad (1)$$

The Backoff timer uses the value of random between 1 et 1+CW[AC][1].
In addition, the CW never exceeds the parameter CWmax[AC], which is the maximum possible value for contention windows associated with each access categories[1].
In this paper we focus on two schemes, the slow decrease and the dynamic tuning of the minimum contention window (CWmin). We compare the performance of the proposed scheme with both EDCF and the Slow Decrease scheme (SD).
This paper is organized as follows. In section 2, we present the problem and the proposed schemes: slow decrease and dynamic tuning of CWmin. In section 3, the simulation topology and parameters are described. We discuss the simulations results and the performance of our schemes in section 4. Finally, in section 5 we give some concluding remarks along with proposing future work.

2. FORMULATION OF PROBLEM AND SOLUTIONS

In the DCF scheme, all stations compete for the resources and channel with the same priorities. The number of collisions increases with the number of stations. Throughput degradation and high delays are caused by the increasing time needed by contending stations to access the channel.
Despite the enhancement introduced by IEEE 802.11e, it is enable to detect the number of stations contending the medium simultaneously.
EDCF reduce the internal collisions in one station but the external ones are always high in the network. If a station, sending a packet of a traffic category (TC), doesn't receive an acknowledgement, it concludes a high level of congestion.

But, if the transmission succeeds, if the CW[AC] is reset to CWmin[AC].
The success of transmission doesn't mean a low level of congestion but it corresponds to a convenient size of contention window (CWac]). Thus, we must keep its size as higher as the level of congestion.
In this case, we propose two schemes. Slow decrease as a static scheme and the dynamic tuning of CWmin.

2.1. Slow Decrease

For each traffic category, two approaches are defined [2]:

- ❖ Multiplicative approach

$$decr\ (CW\ [AC\ ])\ =\ \delta_{ACi}\ *\ CW\ [AC\ ] \quad (2)$$

δ between 0 and 1.

- ❖ Linear approach

$$decr\ (CW\ [AC\ ])\ =\ CW\ [AC\ ] - \alpha_{ACi} \quad (3)$$

α between 0 and CWmax[AC] - CWmin[AC]

Finally, after a successful transmission, the new CW [AC] is given by:

$$CW[AC] = \max(CW\min[AC], decr(CW[AC])) \quad (4)$$

2.2. Dynamic tuning of CWmin

This scheme propose for each access category an adaptive way to update CWmin[AC][3].

Step1: Instantaneous collision rate at the *jth* update period.

$$f_{curr}^{j} = \frac{Num\ (collision_j[p])}{Num\ (data\_sent_j[p])} \quad (5)$$

$Num\ (collision_j[p])$: number of collisions at station p during the period j.

$Num\ (data\_sent_j[p])$: number of packets sent during the update period *Tupdate*.

Step 2: average of collision rate at step *j*.

In order to get an estimation of the collision rate that minimizes random fluctuations, an Exponentially Weighted Moving Average (EWMA) is used to smooth the series of collision rates.

$$f_{avg}^{j} = (1-\alpha)\times f_{curr}^{j} + \alpha \times f_{avg}^{j-1} \quad (6)$$

α is a smoothing factor in the range [0, 1].

Step 3: expression of DCWmin

$$DCW_{\min}[i] = (1 - f_{avg}^{j})\times CW_{\min}[i] + f_{avg}^{j}\times(CW\max[i] - CW\min[i])\times 2^{i-2}$$

And $DCW_{\min}[i] = \min(DCW_{\min}[i], CW_{\max}[i]) \quad (7)$

Step 4: Setting CW after each collision

$$CW_{new}[i] = \min(CW_{\max}[i], 2\times CW_{old}[i]) \quad (8)$$

3. SIMULATION PARAMETERS AND TOPLOGY

In this paper, we use Ad Hoc topology. We consider 50 wireless terminals (WTs) uniformly distributed in a 100x100m square area communicating with each other two by two. All nodes are within the range of each other; hence no routing protocol is used.
We start simulation at time t = 20 seconds (s). We increase the number of active flows by one every two seconds. Each transmitting for each access category, WT sends data.

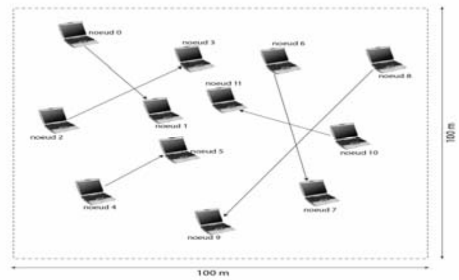


Figure 2. Topology Ad Hoc of 12 nodes

At t = 100s, all traffic sources stop sending except one. At t =150s, all sources end their transmission.

Table 1 shows the different MAC parameters for the all access categories in the different simulation scenarios.

AC	priority	rate	Packet size	Traffic
voice	0	368kbps	92 o	CBR
video	1	1.4Mbps	1464	CBR
Best effort	2	1Mbps	1000o	FTP
Background	3	1Mbps	1000	CBR

Table 1. Simulation parameters [1]

The QoS parameters are throughput and delay [6].

4. SIMULATION RESULTS

4.1 Slow Decrease

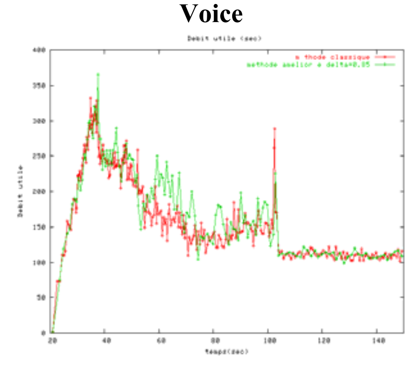
In this paper, we focus on multiplicative approach.
For each access category, we compare two networks: one operating with legacy IEEE 802.11e, and other operating with multiplicative approach.
The results in table 2 are given by different simulations for each access category.

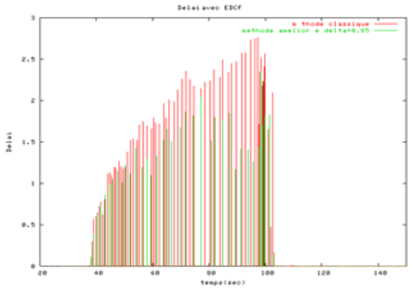
Access category	Size CW	Traffic	δ_{ACi}
Voice	7-15	Real time	0.85
Video	15-31	Real time	0.9
Best effort	31-1023	Non real time	0.95
background	31-1023	Non real time	0.95

Table 2. Results of slow decrease scheme

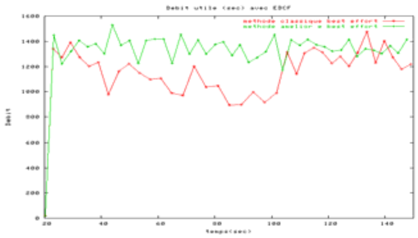
4.1.1. Voice and video

Voice





Best effort



Background

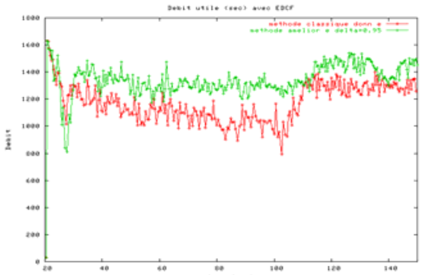


Figure 3. Throughput and delay (Adhoc;classic/Slow decrease)

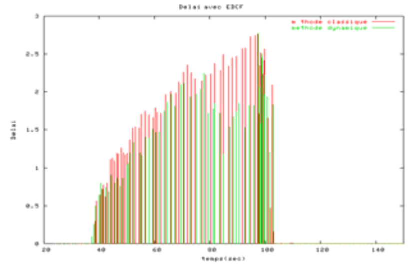
- During the phase of congestion [20 100s], we observe an enhancement in throughput when the size of cw[AC] is equal to the new static value.
- During the phase of decongestion, two curves become confused so the size of cw[AC] is equal to CWmin[AC.
- The multiplicative approach of SD requires a delay lower than the legacy standard, so it has lower jitter. Consequently, it is convenient for the voice and video as real time application.
- During the phase of decongestion of best efooert and bakground, two curves don't become confused because of length of queue.
- The protocol of transport for traffic best effort is TCP, so the transmission is reliable.

4.2 Dynamic tuning of CWmin

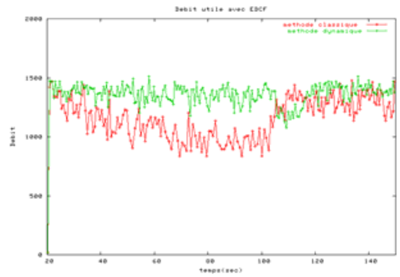
For each access category, we compare two networks: one operating with legacy IEEE 802.11e, and other operating with dynamic method (α=0.6, Tupdate=4000).

4.2.1. Voice and video

Voice



Best effort



Background

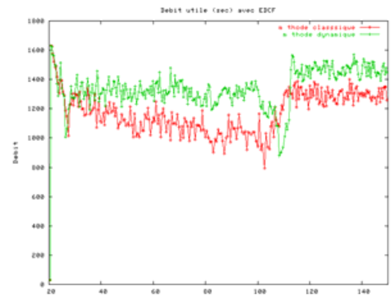


Figure 4. Throughput and delay (Adhoc; classic/dynamic tuning)

- During the phase of congestion [20 100s], we observe an enhancement in throughput when the size of CW is equal to the new dynamic value DCWmin.
- The scheme of dynamic tuning requires a delay lower than the legacy standard, so it has lower jitter. Consequently, it is convenient for the video as real time application.
- For voice, during the phase of decongestion, two curves become confused so the size of CW is equal to CWmin[AC].
- The protocol of transport for traffic best effort is TCP, so the transmission is reliable.

4.3 Performance comparisons of two approaches

4.3.1Gain of throughput

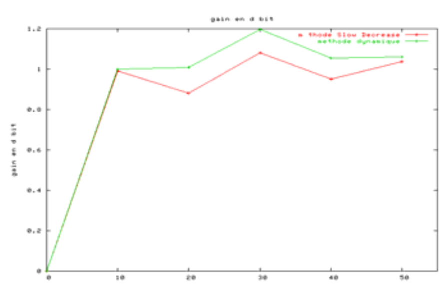


Figure 5. Gain of throughput of voice (Adhoc;SD /dynamic tuning)

The throughput improves in CWmin adaptation. Furthermore, the gain increases when traffic load is greater than 10 stations. The higher performance in throughput for CWmin adaptation is due to the increase in channel utilization because of the dynamic adaptation algorithm.

4.3.2 Mean delay

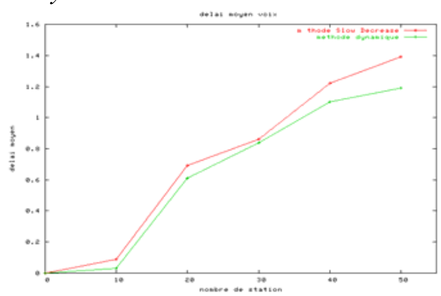


Figure 6. Mean delay of voice (Adhoc;SD /dynamic tuning)

The audio delay in CWmin adaptation scheme is not so lower than SD. We observe that the improvement is not remarkable.

4.3.3 Collision rate

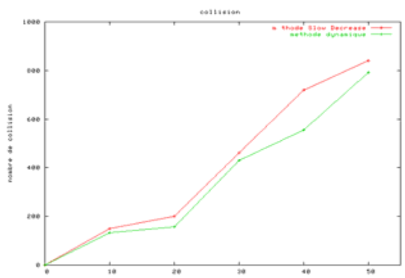


Figure 7. Collision rate voice (Adhoc; SD /dynamic tuning)

The collision rate is the same for CWmin adaptation, and SD for a low traffic of 10 stations. As the traffic increases, the collision rate in CWmin adaptation maintains a lower increase than in SD. It can be seen that, for 40 stations, the collision rate in CWmin adaptation is 40% lower than in SD for voice and 46% for video.

The dynamic adaptation of CWmin has contributed to reduce the number of collisions in the IBSS. This is, because CWmin adaptation adjusts the size of CWmin[i] upon a successful transmission according to the network condition.

5. CONCLUSIONS AND FUTURE WORKS

In this paper, we proposed two methods which treat the case of congestion of wireless networks wich are slow decrease and dynamic tuning of CWmin. We did a lot of simulations of both schemes; we conclude an enhancement with the legacy IEEE 802.11e in throughput and delay. Then we evaluate their performances. We observe a gain of throughput and collision rate in dynamic scheme is better than in SD but it doesn't contribute a remarkable improvement in delay.

As future work, we propose the mapping with EDCF as solution for improvement of QoS in congested environments.

Acronymes

QoS Quality of Service
EDCF Enhanced Distributed Coordination Function
WLAN Wireless Local Area Network
DCF Distributed Coordination Function
AC Access Category
MAC Medium Access Control
TC Traffic Category
CBR Constant Bit Rate
FTP File Transfer Protocol
UP User Priority
CW Contention Window
DCW Dynamic Contention Window
SD Slow Decrease

REFERE NCES

[1]: IEEE 802.11 WG, IEEE 802.11e/D6.0, Draft Supplement to Standard for Telecommunications and Information Exchange between Systems — LAN / MAN Specific Requirements — Part 11: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Medium Access Control (MAC) Enhancements for Quality of Service (QoS), December 2003.

[2] : Imad Aad, Qiang Ni , Chadi Barakat, Thierry Turletti, *Enhancing IEEE 802.11 MAC in congested environments*, INRIA Sophia Antipolis, Rapport de recherche n°4879, Juillet 2003.

[3] : Lassaad Gannoune, Stephan Robert, *Dynamic tuning of the contention window minimum (CWMIN) for enhanced service differentiation in IEEE 802.11 wireless AD-HOC networks,* Ecole d'Ingénieurs du Canton de Vaud (EIVD),Juin 2004.

[4] : Mounir Frifha, Faiza Tabbana*, Amélioration de la norme IEEE 802.11 dans les environnements congestionnés*, SETIT 2005.