Admission Control in IEEE 802.11e EDCA

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Abstract— **The EDCA (Enhanced Distributed Channel Access) mechanism proposed in the IEEE 802.11e draft, allows differentiating traffic channel access with different priorities. However, this method is unable to provide QoS guarantees on its own. In fact, to guarantee certain QoS requirements it is necessary to employ some admission control techniques. This article proposes a new distributed admission control algorithm (DACA) for EDCA mode and evaluates its performance.**
Performed analysis was done by means of a simulator developed in the OPNET platform.

1. INTRODUCTION

As a consequence of the great popularity and implementation simplicity of IEEE 802.11 wireless network standard, numerous investigations are being carried out in order to optimise, enhance and extend its capabilities. In this article we concentrate on work done by Task Group E (TGe) of IEEE 802.11, which is responsible for providing QoS enhancements to the legacy IEEE 802.11 standard. The new supplement provided by TGe, IEEE 802.11e, to the standard is expected to extend the variety of application available for WLAN. Subsequently mixed traffic of multimedia and traditional data application is likely to become reality in the near future in 802.11 wireless networks.
The IEEE 802.11e supplement introduces new mechanism to the MAC layer of legacy standard in order to guarantee QoS requirements. Namely Hybrid Coordination Function (HCF) is suggested to operate with two access types: Enhanced Distributed Channel Access (EDCA) and HCF Controlled Channel Access (HCCA) [1]. They are backward compatible with the legacy 802.11 DCF and PCF schemes and provide different QoS provisioning methods.
In this work we explain and evaluate functionality of an innovative Distributed Admission Control Algorithm (DACA) to be used in EDCA access mode. The DACA mechanism attempts to solve the problem of admission control scheme for distributed system. The difficulty of this task lies in the nature of the access mode, which is completely random. For this reason the primary objective of DACA mechanism is to protect already existing traffic in EDCA. Moreover, the DACA algorithm is supposed to work in WLAN infrastructure mode that, for instance, could be used as one of radio access technologies in an heterogeneous network.

The rest of the paper is organized as follows. Section 2 briefly explains the main QoS concepts related to EDCA. In Section 3 introduction to admission control is given with Distributed Admission Control (DAC) example. The next section presents our proposal of Distributed Admission Control Algorithm (DACA) for EDCA. Section 5 studies DACA performance in multi service scenario. Finally, Section 6 concludes the paper.

2. IEEE 802.11e EDCA – QoS Concept

The Enhanced Distributed Channel Access (EDCA) is a new contention based channel access scheme proposed by TGe[1]. It copes with QoS limitations of Distributed Coordination Function (DCF) access mechanism used in legacy IEEE 802.11 standard [2].

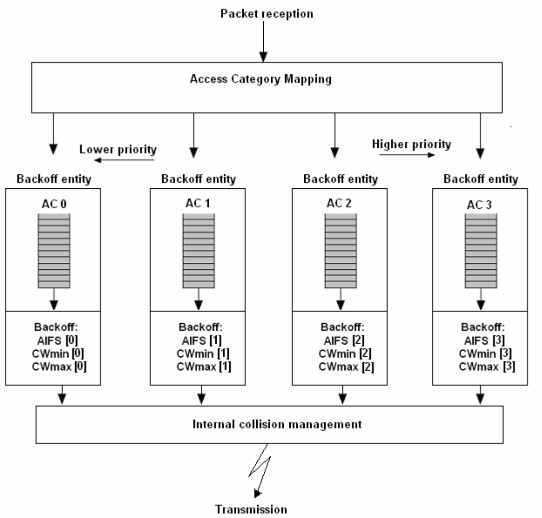

Figure 1: EDCA access mode

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The EDCA enhancements are based on the introduction of Access Categories (AC) with their independent backoff entities. A schematic graphical representation of ACs is shown in Figure 1.
According to [3], IEEE 802.11e stations (referred to as QSTA) should implement four access categories. For each AC, there is a set of EDCA contention parameters associated. Those parameters include: Arbitration Interframe Space AIFS[AC], and Contention Window with its minimum and maximum values CWmin and CWmax respectively.
To gain transmission opportunity each AC from every station competes with other ACs by starting independently a backoff timer after detecting that the channel is idle for an AIFS[AC] interval. The AIFS[AC] value is at least equal to the DIFS value, which is used by the legacy stations to start the backoff procedure, and can be enlarged per AC with the help of the Arbitration Interframe Space Number AIFSN[AC]. The AIFSN[AC] determines the duration of AIFS[AC] according to the equation (1):

$$AIFS[AC] = SIFS + AIFSN[AC] * aSlotTime >= DIFS \quad (1)$$

where SIFS is the short IFS and aSlotTime is a MAC parameter which value depends on PHY layer deployed.
The backoff mechanism of EDCA in general, is similar to the original MAC one, with an added new complexity, referred to as virtual collision, which allows to solve collisions between ACs within one station. In the case of so-called virtual collision the AC with the highest priority win the channel access and other collided entities behave as if they experienced a collision.
The prioritization within this new access mode is achieved by assigning distinct values of EDCA contention parameters to each AC. Consequently, backoff entity that has smaller values of AIFS, CWmin and CWmax has greater probability to access the wireless medium earlier. For more information on the EDCA mechanism please refer to [1,3,4].

3. Admission Control in EDCA

In a decentralized wireless system, the admission control issue is a very complicated task as each station independently decides about the admittance of its new stream. Moreover, to take the correct decision the station needs to know the exact number of available resources in the system. This knowledge, on the other side, in the EDCA access mode, is quite difficult to obtain and in some situations results even impossible.
The problem with the correct estimation of used resources results from the fact that access point (AP) is incapable of knowing a priori the AC of the station that will win the channel contention and will transmit. Consequently, in case of collision or channel error, the AP is unable to determine the ACs of the collided or erroneous packets. Thus, it cannot calculate correctly the number of used resources available for every AC.
The Distributed Admission Control (DAC) algorithm, proposed by the TGe in the Draft 4.0 [1], tries to overcome the problem with resource estimation by implementing a SurplusFactor parameter. The SurplusFactor increases the computed value of the on-air bandwidth of transmitted frames by some additional factor, which takes into account the bandwidth wasted on collisions. The value of SurplusFactor may be constant as suggested in [5] or dynamic. The constant value may result in some inefficiencies because too large values may provoke overestimation of used bandwidth and as a result a system efficiency decrement whereas too small values may make DAC algorithm useless, allowing entrance of too many stations. In the case of dynamic estimation of SurplusFactor a main problem concerns correct calculation of number of retransmissions per AC as well as the AC classes that have suffered collisions. This is due to the fact that the involved AC packets may experience following retransmission situations:

- retransmitted once or many times with finally positive outcome
- retransmitted in the next beacon interval
- retransmitted many times and finally discarded

Therefore, the condition introduced by SurplusFactor is not sufficient as its exact evaluation is neither possible by constant nor by dynamic estimation.
In Figure 2 we demonstrate results for a simple scenario with DAC mechanism implemented with constant SurplusFactor value equal to 1.3.

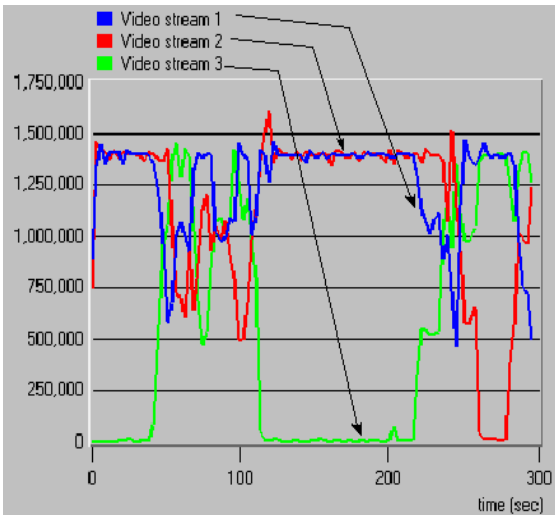

Figure 2: Throughput of video streams with SurplusFactor value of 1.3

The analyzed set-up includes: three video (1400Kbps each), four voice (38Kbps each) and five data (800Kbps each) stations. As we can see the third video station is the last to enter the system and, in fact it is not allowed to enter during the first 20 seconds due to the lack of sufficient resources.

However, due to the problem with correct estimation of the SurplusFactor after 20th second the total transmission time counter for AC2 (video traffic) in AP results too small. This underestimation causes the increment of time budget value for AC2 for the next beacon interval and consequently, allows the third video flow to finally enter the system. Then, with three active video flows the QoS guarantees for the video stream 1 and 2 are lost.

4. Distributed Admission Control Algorithm (DACA)

Similarly to the DAC mechanism, the proposed Distributed Admission Control Algorithm (DACA) is composed of two parts: one executed in AP, and the other in each station.

The station component of the algorithm is reduced to minimum and its responsibilities include:

1. To compute the total occupation time (TOT) per beacon interval;
2. For a given AC, to decide the acceptance or not of the new call depending on the TOT value and a transmission time budget (TTB).;

The TOT parameter is determined according to following equation:

$$TOT = BeaconInterval - \sum_{AC=0}^{3} TTB[AC] \quad (2)$$

If the value of TOT is lower than some threshold value (for instance, in performed experiments 70%) the station directly admits its new flow. In case the TOT value is greater than the specified limit the station verifies whether its entering flow load is lower or equal to the TTB[AC]. The load should be calculated as an average of uplink and downlink load per beacon interval.

This condition is only verified for real time traffic such as audio or video. When the new traffic is of interactive or background nature, they can enter the system if the TTB of their AC is greater than zero. The reason is that this type of traffic could be delayed when needed (congestion situations), by means of contention parameters, without loosing the QoS attributes.

From the point of view of admission control function, the AP role is to evaluate the TTB value for each AC according to expression (3) and send it in a beacon frame.

$$TTB[AC] = \frac{tx\_left[AC]}{SPF[AC]} \quad (3)$$

where tx_left[AC] - specifies the amount of time that has been left unused during the last beacon interval per access category.

SPF[AC] – it is a surplus factor representing the ratio of total time spend on all transmissions of a packet (with corresponding ACKs) to its actual length with employed channel speed.

The expression for calculating the tx_left[AC] time is shown below, where the AP node uses two new parameters: Transmission Time Threshold (TTT[AC]) and Load[AC].

$$tx\_left[AC] = MAX\left(TTT[AC] - Load[AC], 0\right) \quad (4)$$

The TTT[AC] is a crucial parameter of DACA algorithm, which represents the maximum amount of time that may be spend on transmissions of a specific AC per beacon interval. Its value may be constant or may change dynamically. The constant value of TTT[AC] is an optimum solution only for individual situation but, when service mix distribution changes with time the constant threshold is ineffective. Therefore, in our work, dynamic tuning of TTT[AC] have to be applied, which may depend on parameters like: current load per AC, contention window size, number of stations, type of application, etc.

The Load[AC] attribute corresponds to the total time occupied by transmissions from each AC per beacon interval. Its value is computed differently for real time and burst type traffics. For continuous type of flows equation (5) is applied:

$$Load[AC] = MAX\begin{pmatrix} tx\_time[AC] * SPF[AC] \ , \\ beacon\_load[AC] \end{pmatrix} \quad (5)$$

where tx_time[AC] – is a set of counters that indicate the total time on-air of the frames during beacon interval;

beacon_load[AC] – corresponds to the average load that could be introduced during a beacon interval by all admitted streams within each AC;

As a load of the non-real time applications is not known a priori, due to its bursty nature, the AP establishes a minimum load average, known as average guaranteed rate (GuaranteedRate). By means of the GuaranteedRate and transmission time threshold, the AP is able to estimate the load of active burst flows and control their number. Hence, the Load[AC] parameter is calculated as follows:

$$Load[AC] = GuaranteedRate * admitted\_strm\_num[AC] \quad (6)$$

where admitted_strm_num[AC] – refers to the number of all admitted streams within each AC.

Besides the distributed part of DACA mechanism, the AP also performs some centralized decisions, taking care of the case when two or more flows try to enter the system in the same beacon interval and there is no sufficient time for placing all of them.. According with aforementioned explanation all the flows will satisfy the condition and will be admitted. Therefore to avoid this problem the station admits its new traffic if it receives an ACK after first packet sent (trial packet). However, the lack of the ACK is considered by a station as a packet loss thus, it will try to retransmit it. Then, to limit the number of retransmitted trial packets each station rejects its new traffic after three missing acknowledgement, obviously assuming that a new beacon frame with updated parameters is not received earlier.

To manage this new centralized situation, the AP needs a continuous control of TTB[AC] time. In addition, to know at each moment the minimum occupation time, the implementation of two new tables (the number of admitted stations and the number of stations accepted in the current beacon interval) is needed in AP.

5. DACA performance evaluation

To assess and validate the effectiveness of DACA algorithm a single QBSS cell was assumed with increasing number of station with following service mix distribution: voice 50%, video 16% and web 34%.The voice traffic is generated as G.729 A/B VoIP application with transmission rate of 24kbps.To model the video stream a Group of Pictures (GOP) of 12 was used with 25 frames per second and 128 kbps transmission rate in downlink and CBR of 16 kbps in uplink. The traffic model for web traffic, [6], considers the generation of activity periods (i.e. pages for www browsing), where several information packets are generated and a certain thinking time between them exists, reflecting service interactivity. The specific parameters are: time between pages: avg. 4sec. UL/5.17sec. DL; average number of packets arrival per page 25 (UL/DL); number of bytes per packet: 1000 bytes maximum 60000 (truncated Pareto distribution); time between packets arrival: avg. 0.03125 UL/0.015625 DL exponentially distributed.

Each station operates with IEEE 802.11b physical layer with channel rate of 11Mbps. The EDCA contention parameters used for each AC are presented in Table 1.

Table 1: EDCA contention parameters

AC	AIFSN	CWmin	CWmax
1	3	31	1023
2	2	15	31
3	2	7	15

The beacon interval is equal to 100 ms and TTT[AC] time at the beginning is the same for each traffic and equal to 30 ms. The remaining time (10 ms) is used to absorb the traffic fluctuations. The TTT[AC] value is adjusted dynamically and is proportional to the service mix distribution. Moreover, to limit the number of collisions due to the small size of CW for voice traffic the maximum TTT[AC3] is determined as a function of CW size and station number and is equal to 54 ms.

Figure 3 shows the aggregated throughput for voice traffics with and without admission control. We observe that without the DACA algorithm the throughput starts to oscillate when system load is very heavy (18 stations). Although without admission control all stations are allowed to enter the system the aggregated throughput for voice traffic does not increase but fluctuates. In consequence, QoS cannot be guaranteed.

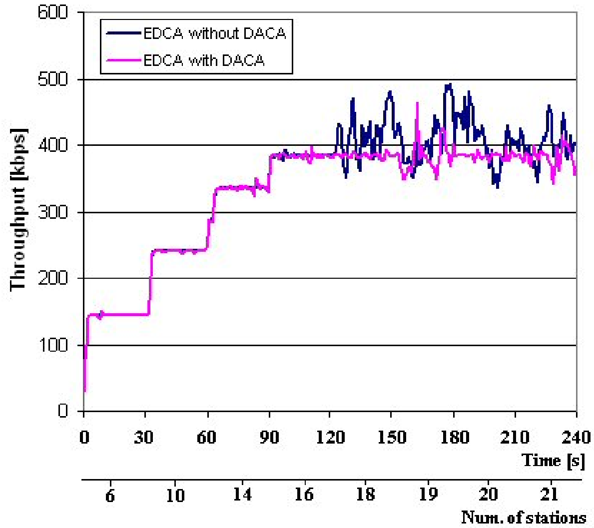

Figure 3: Aggregated throughput for voice traffic with and without DACA algorithmt

With admission control mechanism we can see that when system reaches the heavy load state no more stations are admitted and already active stations are protected.

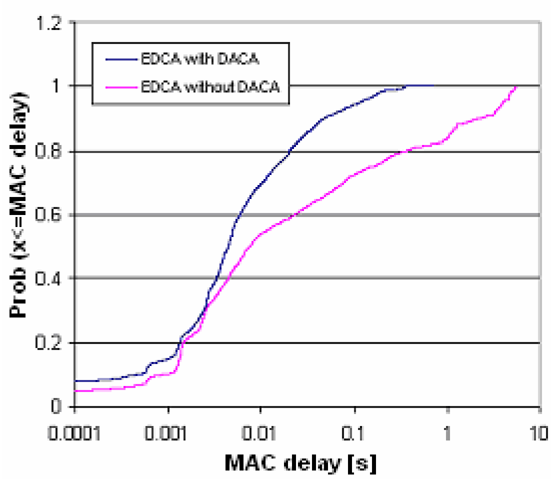

Figure 4: CDF for video MAC delay with and without DACA algorithm

Figure 4 demonstrates the cumulative distribution function of MAC delay for video traffic with and without admission control. Comparing this two plots we observe that without admission control the MAC delay of 95% of packets is lower than 3.84 s, whereas in case of DACA mechanism MAC delay for the same case is lower than 0.11 s. Accordingly, video station in set-up without DACA algorithm are not guaranteed their QoS expectative .

Figure 5 shows the development of TTT[AC] value and Figure 6 the corresponding total occupation time for each AC, Load[AC] parameter.

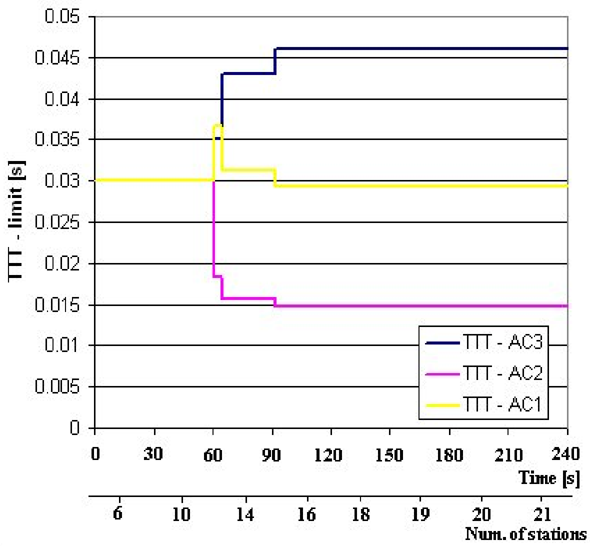

Figure 5: TTT[AC] time tuning with increasing number of stations

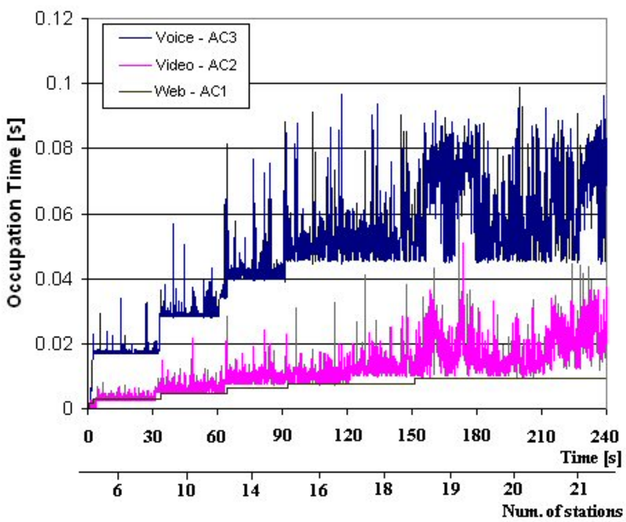

Figure 6: Total occupation time for each AC

We observe that TTT [AC] parameter tuning follows the service mix distribution as AC 3 limit reaches 50% of 90ms and TTT value for AC1 is double the limit for AC2. Moreover, the Figure 6 shows that minimum average load for each AC, beacon_load[AC] parameter, does not exceed the fixed limits. The oscillations of occupation time corresponds to tx_time[AC] * SPF[AC] product of Load[AC], which are conditioned by elevated number of collisions resulted from high system load. However, QoS guarantees of each flow are not affected.

6. Conclusions

In this paper a new distributed admission control algorithm was presented for enhanced distributed channel access mode of IEEE 802.11e standard. We evaluate the performance of the algorithm for different traffic streams and demonstrate that algorithm can guarantee QoS requirements for each type of application in all system load conditions. Moreover, the DACA algorithm only change a small part of original beacon frame as instead of occupied time per beacon interval (Load) the available time per beacon interval is sent (TTB[AC]).

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