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Service differentiation in the IEEE 802.11e

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I. INTRODUCTION

The evolution of the 802.11 is in the direction of making it fully mature in supporting a variety of applications (data, audio/video, VoIP) in order to make the Wireless LAN (WLAN) paradigm positively competitive. One of the main objective of the research activities in this field is the design of suitable mechanisms to support Quality of Service (QoS) and to efficiently accommodate in the WLAN different data flows.
In 802.11 WLANs, all stations within a Basic Service Set (BSS) share access to the same radio channel. In order to preserve the flexibility given by a fully distributed access scheme, service differentiation mechanisms shall be introduced as MAC layer extensions.

The 802.11 Working Group initiated a Task Group (TG11e) with the aim of enhancing the 802.11 MAC to support applications with QoS requirements [1]. This has led to the definition of new mechanisms able to differentiate the channel access for different traffic classes while maintaining backward compatibility with the 802.11-99 standard [2]. The current 802.11 standard [2] suffers form the lack of QoS support. Limitations of 802.11 WLANs in providing QoS can be summarized as follows:

- the nominal bandwidth is equal to 11 Mbit/s; however, peak data rate depends on the distance between transmitter and receiver, on the presence of obstacles and often it degrades to a lower bit rate; the actual available bandwidth is between 50% and 70% of the nominal value;
- due to the collision-based channel access, packet delivery delay and inter-packet delay jitter are typically quite high giving no assurances to QoS sensitive traffics;
- all stations access the medium with the same rules, thus no differentiation can be made among stations with different QoS requirements;
- it may happen that uplink and downlink flows unfairly share the bandwidth.

In this report, the main principles of the 802.11e are described and related performance results are discussed. The report is structured as follows. Section II briefly describes the 802.11e. Section III is complectly dedicated to the analysis of the performance that we can expect by adopting the new mechanisms introduced in the 802.11e. Sub-Section III-A highlights difference is supporting a delay bounded flows with the controlled-access methods and the collision based ones. Mechanisms to balance downlink and uplink bandwidth sharing are presented in the Section III-B. Finally, Section IV concludes the work.

II. 802.11E: AN OVERVIEW

In the 802.11e an *Hybrid Coordination Function* (HCF) is introduced to manage the access to the medium. Two different access methods are defined, namely the *Enhanced Distributed Channel Access* (EDCA), and the controlled based access procedure (*HCF Controlled Channel Access* - HCCA). The access to the medium is organized in subsequent superframes in the time domain. A superframe is divided in a *Contention Free Period* (CFP) and a *Contention Period* (CP) (see Figure 1). The main innovation of the 802.11e is that in the CP, a centralized manager named *Hybrid Coordinator* (HC), typically co-located in the *Access Point* (AP), can initiate transmission periods that will be handled without contentions. These periods are named *Controlled Access Periods* (CAPs) and are provided to serve sensitive QoS flows.
CFP and CP alternate in a superframe under the HC control. The resulting scheme is that HCCA is provided both during CFP and CAPs whereas the EDCA is applied only in the CP.

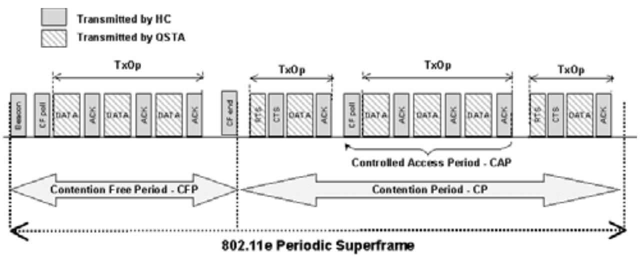


Fig. 1. The 802.11e superframe

The IEEE 802.11e introduces both a *Prioritization* (handled by the EDCA) and a *Parametrization* (managed by using the HCCA) of the different traffic flows.
Different service classes are introduced, characterized by 8 user priorities. The 8 priorities are distinguished according to IEEE 802.1D guidelines and are mapped into:

- 8 *Traffic Categories* (TC), with a-priori QoS parameters setting, mapped on their turn into four MAC layer queues called *Access Categories* (AC);
- 8 *Traffic Streams* (TS) for which QoS characteristics are negotiated by *Traffic Specifications*; these TSs flow into 8 MAC queues.

For both ACs and TSs, different priority levels are defined. The ACs are handled by the EDCA during the CP whereas TSs are served by employing HCCA during CFP and CAPs. In this latter case a centralized control is implemented in the HC.

Medium contention rules in the CP are the same as in the basic 802.11 *Distributed Contention Function* (DCF), i.e., a station waits until the channel is idle for a given amount of time and then it emits the MAC frame. If the channel is busy or if a collision has occurred on it, the station retries frame transmission following an exponential backoff rule. Service differentiation in contention mode is obtained by adopting different settings for the channel access parameters of each AC.
Two types of parameters are used:

- the time period a station shall wait for a transmission after it has sensed the channel idle, namely the *Arbitration Inter Frame Space* ($AIFS$), expressed as a multiple of a $SlotTime = 20\mu s$;
- the *Backoff Interval* (BI) computed as a function of the *Contention Window* (CW) in accordance to the expression $BI = SlotTime \cdot random[0, CW]$.

The CW is computed starting from a CW_{min}. If the backoff procedure is invoked because of a collision event, the CW value is updated as $CW = (CW + 1) \cdot 2 - 1$.
If, after repeated updates, CW reaches the CW_{max}, the contention window is maintained unchanged till a successful transmission occurs. After a successful transmission, CW is reset to CW_{min}.
By indicating with ACi_{low} and ACj_{hi} the i-th and the j-th MAC queue respectively, where the former has lower traffic priority than the latter, the relationship between access parameters is:

$$AIFS[ACj_{hi}] < AIFS[ACi_{low}] \tag{1}$$

$$CW_{min,max}[ACj_{hi}] < CW_{min,max}[ACi_{low}] \tag{2}$$

In this way a sensitive QoS traffic is associated with AC_{hi}; this grants a higher probability to access the medium (by means of (1)) and a reduced lag time in backoff mode (by means of (2)).

To achieve a better medium utilization and to provide a further means to differentiate service levels, EDCA may exploit packet bursting: once a station has gained access to the medium, it can send more than one MAC frame without contending again for the medium, provided that the total access time does not exceed a $TxOpLimit$ (*Transmission Opportunity limit)* bound. In the 802.11e Draft, the $TXOP$ is the time dedicated to the transmission of consecutive MAC frames of the same station. Additional details can be found in [3][4][5]. Table II reports the default EDCA parameters setting for the 4 AC classes.

TABLE I
DEFAULT EDCA ACCESS PARAMETERS PROPOSED IN THE 802.11E DRAFT 8

EDCATraffic	$AC0$	$AC1$
$AIFS$	7	3
$TxOpLimit$	$-$	$-$
CW_{min}	$aCW_{min} = 31$	$aCW_{min} = 31$
CW_{max}	$aCW_{max} = 1023$	$aCW_{max} = 1023$
EDCATraffic	$AC2$	$AC3$
$AIFS$	2	2
$TxOpLimit$	$6016\mu s$	$3264\mu s$
CW_{min}	$(aCW_{min} + 1) \div 2 - 1$	$(aCW_{min} + 1) \div 4 - 1$
CW_{max}	aCW_{min}	$(aCW_{min} + 1) \div 2 - 1$

The rule governing the EDCA CWs setting is that two integer variables, named ECW_{min} and ECW_{max}, in the range $[0, 15]$, can be selected to derive the variables aCW_{min} and aCW_{max} as follows:

$$aCW_{min} = (2^{ECW_{min}} - 1) \tag{3}$$

$$aCW_{max} = (2^{ECW_{max}} - 1) \tag{4}$$

As a consequence the minimum encoded value of CW_{min} and CW_{max} is 0, and the maximum value is 32767.

In the framework of the 802.11e a lot of effort has been dedicated to evaluate the HCCA (see papers [3][6][7][8]) and the EDCA (see works in [5][9][10][11][12][13][14][15][16][17][18])). The most of these papers deal with a comparison of the two schemes, or to a comparison with the previous 802.11b standard, and to the definition of appropriate admission control schemes and schedulings able to make the HCCA/EDCA effective in supporting the QoS. In this report key performance results, derived from an extensive simulative analysis, are reported and the potentialities of the 802.11e are discussed.

III. Traffic differentiation via 802.11e

Flows to be supported in the WLAN may be different both in terms of emission characteristics and QoS requirements. A simulation tool has been implemented by reproducing the main functions and procedures included in the Draft 8 standard.

The considered scenario includes an AP and several QSTAs in a single BSS. Radio channel is assumed to be error free and no hidden terminals are present. The channel bit rate is assumed equal to 11 Mbit/s.

In all the simulations the traffic is symmetric: for each flow transmitted in the uplink there is a symmetric flow to be transmitted in the downlink. This is assumed for each class of traffic.

A possible mapping of QoS flows (i.e., VoIP, video-streaming, video-conference) and best effort services (i.e., E-mail, FTP, HTTP) in the TCs is provided in Table II where also the traffic characteristics are listed. The $TC0 - TC3$ are conceived to accommodate best effort traffic modelled as ON-OFF sources. QoS traffic sources ($TC4$-$TC5$) have an exponential negative inter-arrival packet distribution with average bit rates reported in Table II.

In accordance to the standard $TC0$, $TC1$ and $TC2$ are mapped to $AC0$, $TC3$ to $AC1$, $TC4$ and $TC4$ to $AC2$ and finally $TC6$ and $TC7$ are mapped to $AC3$.

TABLE II

Traffic flows parameters and QoS requirements

Traffic Category	$TC0$	$TC1$	$TC2$	$TC3$
Type of Service	*E-mail*	*FTP*	-	*HTTP*
Delay (ms)	700	450	450	600
PacketLength(bit)	10K	10K	10K	10K
Mean BitRate(kbit/s)	386	637	637	496
Peak BitRate(kbit/s)	545	1220	1220	790
Traffic Category	$TC4$	$TC5$	$TC6$	$TC7$
Type of service	*Video streaming*	*Video Conference*	*VoIP*	*VoIP H.Q.*
Delay (ms)	150	100	70	60
PacketLength(bit)	12K	12K	480	480
Mean BitRate(kbit/s)	400	200	16	64

For each class of traffic it is assumed the MAC frames can accommodate an entire packet.

All simulation curves are plotted till the saturation threshold, i.e., till the overall bandwidth is saturated by the transmissions of the different stations in the BSS.

A. Results on the QoS support in 802.11e

This section presents some numerical results of the simulation activity concerning the QoS enhancement obtained with IEEE 802.11e. In the considered scenarios low and high priority traffic classes are delivered contemporarily. The behavior of the high priority flow (Video-conference) is monitored as a function of: (i) adopted access method (EDCA or HCCA); (ii) traffic type transmitted by the other QSTAs in the BSS; (iii) amount of traffic loading the BSS.

In the first simulation study, the traffic generated by a video-conference is mapped into $AC2$ class and is delivered employing a pure EDCA mode. Subsequently the same traffic is mapped into $TS5$ and scheduled by HCCA rules. The numerical results are in Figures 2 and 3. Figure 2 reports the average delays that video-conference ($TC5$), MAC frames perceive in the path from a source QSTA to a destination QSTA in the same BSS. Figure 3 plots the respective throughput. Both delay and throughput are evaluated as a function of the increasing number of QSTAs in the BSS which deliver contemporarily the four ($AC0$, $AC1$, $AC2$ and $AC3$) traffic flows.

It can be observed that, although the EDCA mechanism is conceived for differentiating traffic in contention mode, it is not able to contribute for a guaranteed QoS support when compared with the HCCA. As a consequence, the HCCA must be mandatorily introduced to properly handle time bounded traffics with strict QoS requirements.

When the number of QSTAs operating in the BSS is below a given value (of about 13 in Figure 2), EDCA satisfactorily supports QoS traffic as well as the HCCA. On the contrary, when the number of flows increases, performance of EDCA decrease. To protect QoS flows from the variability of network conditions, HCCA is introduced. As Figures 2 and 3 show, HCCA allows the high priority traffic requirements to be guaranteed even if the BSS QSTAs number increases. Delay and throughput obtained for a video-conference flow with HCCA are almost independent from the BSS load. Moreover, the measured maximum delay perceived by the video-conference flow is maintained below the negotiated threshold ($100\,ms$ as reported in Table II).

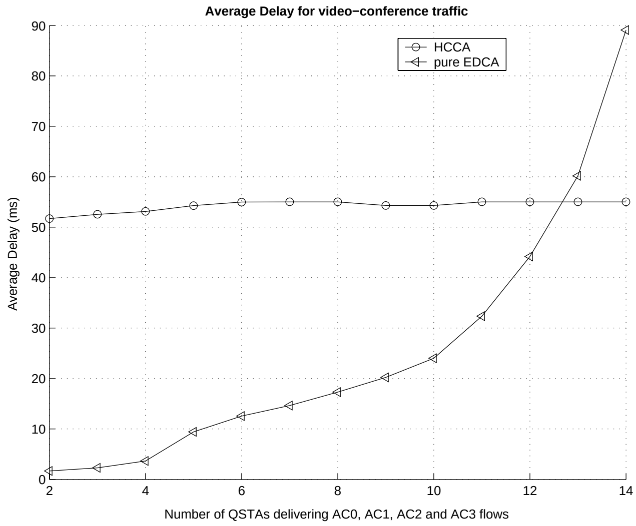


Fig. 2. Average delays of a Video-conference transferred via EDCA or via HCCA

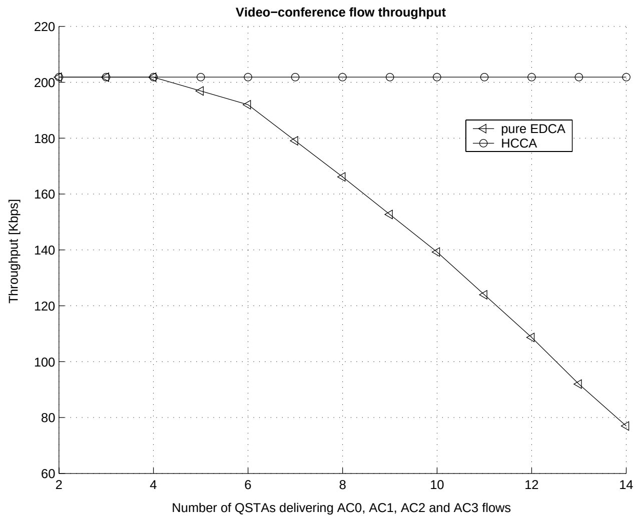


Fig. 3. Average throughput of a Video-conference transferred via EDCA or via HCCA

B. Results on the uplink and downlink differentiation

In addition to the possibility to handle different types of QoS flows, the 802.11e shall guarantee a differentiation between downlink and uplink flows and specifically guarantee that the most loaded direction (typically the downlink) has sufficient bandwidth to deliver its data.

Consider a pure EDCA access mode and one of the four ACs (let say AC_x) and assume that traffic exchanged in the BSS is symmetric, i.e., the same amount of traffic goes in uplink and downlink directions. In this scenario N QSTAs contend the medium for the traffic type belonging to the AC_x. This traffic goes in the direction QSTAs-AP (uplink). Contemporarily, the AP has to sustain N AC_x traffic flows directed to the QSTAs (downlink). The AP also contends the medium to transmit these flows. The whole traffic in downlink relies on a unique queue in the AP dedicated to the AC_x (see Figure 4 with an example of a BSS with N QSTAs and 1 AP).

For the generic AC_x is:

- q_x the transmitting MAC queue that serves an uplink traffic flow in a QSTA;
- Q_x the transmitting MAC queue serving downlink flows in the AP.

Wheras in a QSTA q_x has to serve only frames belonging to a single AC_x, in the AP, Q_x serves N flows of AC_x type directed to the QSTAs. The throughput that Q_x should sustain in the downlink is N times the throughput of q_x. The legacy 802.11 and the 802.11e extension provide a unique contention access mechanism for both QSTAs and AP by assigning the same number of AC queues and the same rules to manage contention access mode in the two devices. Both devices use the same EDCA access parameters (i.e., $AIFS$, CWs and $TxOpLimit$ values) for a given traffic type as shown in Table II. The immediate conclusion is that when the number of QSTAs with the same AC increases, the overall system performance rapidly

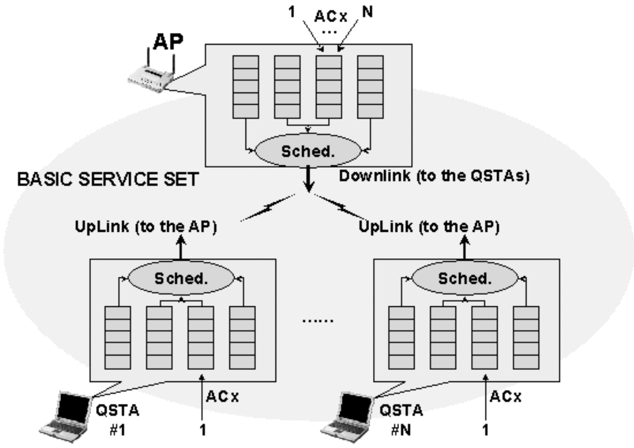


Fig. 4. Example of BSS constituted by N QSTAs and 1 AP

decrease; specifically the AP could not be able to properly sustain the downlink flows when competing with the QSTAs. The consequence is that AP buffers overflow and unacceptable frame delivery delays occur.
It is to be noticed that similar unfairness problems occur also when the traffic is not symmetric, i.e., when the AP has higher loads to be transmitted in the downlink compared to the QSTAs in the uplink. This latter case refers to the download of files form the Internet via the AP, that is quite likely in a WLAN.

The unfairness problem between uplink and downlink traffic in a 802.11 centralized structure has been partially addressed in the literature. In [7] the authors highlight the disadvantages caused by the unfairness, especially when the number of stations increases. A proposal to reduce this drawback is given in [19] and [20]. In these works the 802.11b is considered; authors operate at *Logical Link Control* (LLC) layer. In the LLC AP a number of queues equal to the number of Wireless Stations (WS) is introduced; on the other hand, each WS is equipped with only one queue. A scheduling algorithm is then introduced to suitably pass the LLC frames to the MAC layer. In [19], to allow a fair share of the available bandwidth between uplink and downlink streams, AP MAC queue is provided with a lower CW value than WSs' queues. The work in [20] considers unfairness at the TCP layer due to different channel behaviors at the physical 802.11 layer. Authors propose an algorithm which improves the fairness among WSs that experience short channel failures.

C. Access Point Prioritization (APP)

To mitigate the uplink and downlink unfairness, it is possible to maximize the probability that an AP succeeds in accessing the medium compared to the QSTAs. This could be achieved by employing different sets of EDCA parameters for AP and QSTAs.
This differentiation in access priority can be easily, and with a low amount of extra-effort, obtained by (i) tuning $AIFS$s providing the AP with lower values than QSTAs; (ii) increasing the CW_{min} - CW_{max} range used by every QSTA to compute the BI. The EDCA parameters configuration can be fixed at the network set-up or can be arranged dynamically as a function of the current network load.

To set the EDCA parameters some constraints indicated in the Draft 8 must be considered (see Table II for the rules governing the relationships among the different values). A possible parameters configurations (selected by analyzing different possibilities) is the one of Table III for the AP (downlink) and the one of Table IV for the uplink (i.e., for the QSTAs).
The AP aCW_{min} field has a value equal to 31 and aCW_{max} = 1023 (resulting from the choice of ECW_{min} = 5 and ECW_{max} = 10, respectively). On the other hand, the aCW_{min} of a QSTA is 63 (ECW_{min} = 6) whereas the aCW_{max} is 1023 as for the AP.
The selection of a $aCW_{min} = 31$ in the AP downlink is made in accordance to the following considerations that have been confirmed by experimental results:

1) a lower value of aCW_{min} is the one corresponded to $ECW_{min} = 4$, i.e., $aCW_{min} = 15$ (see Eq. 3);
2) the consequence of item (1) is that the parameters setting for $AC2$ and $AC3$ traffic flows, in accordance to Table II, is a range of CW=[7,15] for $AC2$ and CW=[3,7] for $AC3$;
3) $AC2$ and $AC3$ with the parameters as in item (2) very frequently win the medium whereas $AC1$ and $AC0$ do not have hardly ever access to the channel, experiencing very low performance.

As far as the $AIFS$s differentiation between uplink and downlink is concerned, the legacy $AIFS$ for the AP is decremented by one $SlotTime$. This choice on one hand, as will be show in the following, in effective in balancing the uplink and downlink when combined with the appropriate CW selection, and on the other hand guarantees that the QSTAs remain fully compliant with the basic 802.11.

TABLE III

APP DOWNLINK EDCA ACCESS PARAMETERS

EDCA Traffic	$AC0$	$AC1$	$AC2$	$AC3$
$AIFS$	6	2	1	1
$TxOpLimit$ (μs)	2208	3264	6016	3264
CW_{min}	31	31	15	7
CW_{max}	1023	1023	31	15

TABLE IV

APP UPLINK EDCA ACCESS PARAMETERS

EDCA Traffic	$AC0$	$AC1$	$AC2$	$AC3$
$AIFS$	7	3	2	2
$TxOpLimit$ (μs)	2208	3264	6016	3264
CW_{min}	63	63	31	15
CW_{max}	1023	1023	63	31

D. Transmission Opportunity limit Differentiation

In addition to CW and $AIFS$ differentiation, the uplink and downlink could also be differentiated by means of the *Transmission Opportunity limit (TxOpLimit)*.

As stated in Section I the *TxOpLimit* is the maximum duration of a $TXOP$ period that a station can used to transmit consecutive MAC frames once it gains the access to the medium.

By using a *Transmission Opportunity limit Differentiation* (TOD), a higher *TxOpLimit* value is assigned to the AP (compared to the QSTAs). In this way, the AP, besides the priority achieved by the APP mechanism, will be able to dedicate more time for its frames transmission.

Two different settings are evaluated:

1) TOD1: the AP uses the maximum value defined by the Draft that is $6016\mu s$ for all the AC classes. The QSTAs use the same values of the basic configuration with the exception of $AC2$ that has a *TxOpLimit*= $3264\mu s$ instead of $6016\mu s$. In this way, we always attribute a higher priority to the AP than to the QSTAs (compare Tables V and VI).
2) TOD2: in this second setting, the *TxOpLimit* for the AP is fixed to $4000\mu s$; this value is the result of a tradeoff between selecting a value less than the maximum and still differentiating AP and QSTAs, that in TOD2 are assumed to maintain the same values of TOD1.

Remind that the *TxOpLimit* is defined as units of $32\mu s$.

The two settings indicated above are the result of an analysis of the performance achieved by varying the *TxOpLimit*. This analysis showed that, in order to have a perceptible difference in the measured performance, rather a lot of units shall be varied in the *TxOpLimit* values. The two selected cases refer to an AP with a maximum *TxOpLimit* value and a medium one; for the QSTAs *TxOpLimit* the values are maintained in line with the basic 802.11 standard.

Figures 5(a), 5(b), 5(c) show a comparison of delays encountered when APP (solid lines) is applied with respect to the pure EDCA scheme (dashed curves). Each Figure reports the average frame delay for a give AC class as a function of increasing

TABLE V

TOD DOWNLINK EDCA TXOPLIMITS

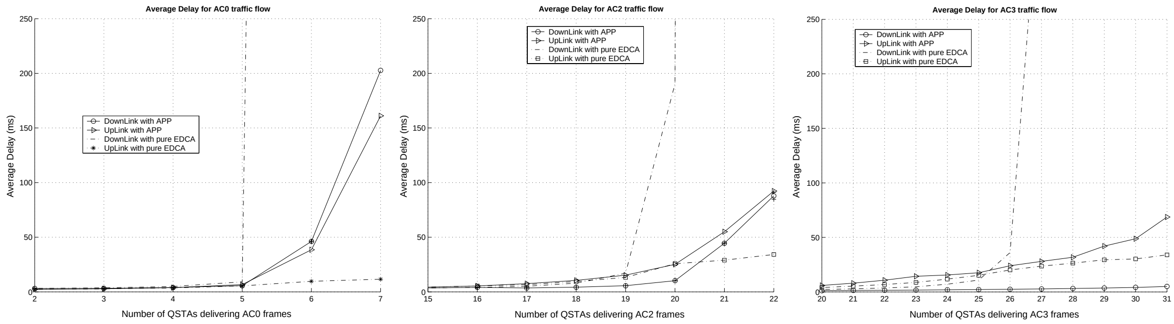
TxOplimit (μs)	$AC0$	$AC1$	$AC2$	$AC3$
$TOD1$	6016	6016	6016	6016
$TOD2$	4000	4000	4000	4000

TABLE VI

TOD UPLINK EDCA TXOPLIMITS

TxOplimit (μs)	$AC0$	$AC1$	$AC2$	$AC3$
$TOD1$	2208	3264	3264	3264
$TOD2$	2208	3264	3264	3264

correspondent traffic in the BSS. In each of the three cases every QSTA transmits only one AC flow. Dashed curves are derived by assuming that both AP and QSTAs are characterized by the same EDCA access parameters (i.e., $aCW_{min} = 31$ and $aCW_{max} = 1023$ for both the AP and the QSTAs). Solid lines refer to the implementation that includes the APP.



(a) $AC0$ traffic (b) $AC2$ traffic (c) $AC3$ traffic

Fig. 5. Average packet delay for the AC traffic as a function of the increasing number of the same AC flows in the BSS

It can be observed that the higher is the number of QSTAs with the same AC flows in the system, the deeper is the unfairness between uplink and downlink. As the number of QSTAs, characterized by a given AC traffic, increases, the correspondent AC queue in the AP becomes overloaded. This gives rise to a threshold beyond which downlink and uplink delays rapidly diverge. This threshold is 5 QSTAs in Figure 5(a), 20 in Figure 5(b) and 26 in Figure 5(c).

Whereas the pure EDCA maintains the same access priorities for the AP and the QSTAs, the APP gives priority to the AP. Solid lines show how APP provides effectively the AP an higher priority in contention mode granting to it a higher probability to win the access competition. Effects of this priority are evident when the load increases. When APP is applied, an overall system performance improvement is achieved. As shown in Figures 5(b) and 5(c), APP is suitable to improve performance of a system carrying QoS traffic. We recall that whereas $AC0$ accommodate best effort traffic, the other two classes ($AC2$ and $AC3$) queue delay-bounded frames. In a pure EDCA, $AC2$ (see Figure 5(b)) and $AC3$ (see Figure 5(c)) frames are extremely penalized in the downlink, thus causing an overall performance degradation. Traffic transmitted by some QSTAs is delayed beyond the admissible values (see Table II). The proposed APP approach, by reducing the lag time in the AP queues, produces a significant decrease of delivery delays in high loaded traffic conditions and allows the system to satisfactorily handle QoS requirements even if the number of QSTAs increases beyond the threshold determined by a pure EDCA behavior.

A second set of simulations has been carried out by considering also the TOD mechanism. Three different configurations have been considered:

- TOD1 combined with APP (named $TXOP-1$)
- TOD2 combined with APP (named $TXOP-2$)
- TOD1 combined with legacy CW and $AIFS$ (named $TXOP-3$).

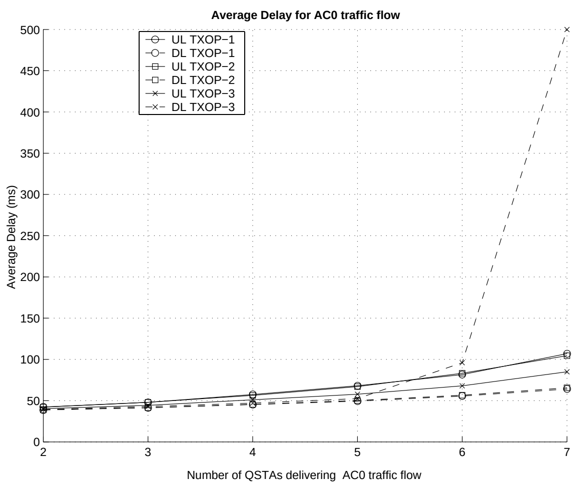


Fig. 6. Average packet delay for $AC0$ as a function of the increasing number of $AC0$ flows in the BSS

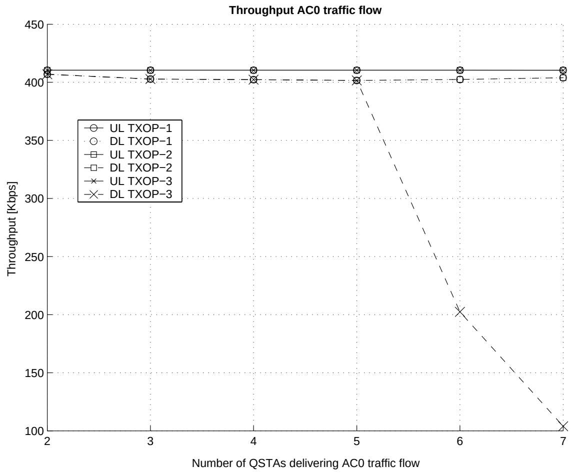


Fig. 7. Average throughput for $AC0$ frames as a function of the increasing number of $AC0$ flow in the BSS

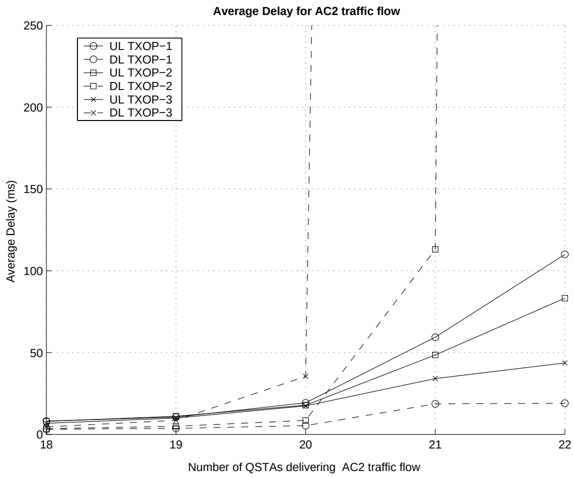


Fig. 8. Average packet delay for $AC2$ as a function of the increasing number of $AC2$ flows in the BSS

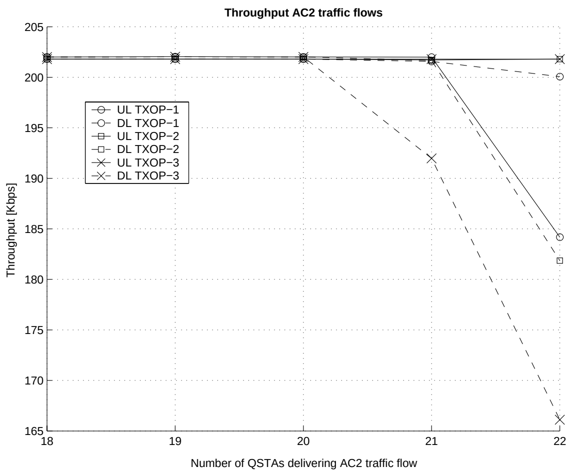


Fig. 9. Average throughput for $AC2$ frames as a function of the increasing number of $AC2$ flow in the BSS

Figure 6 shows the uplink and downlink delays measured in the three schemes for the AC0 traffic flow. The companion Figure 7 plots the corresponding throughput.

We can state that by adding the TOD mechanism the delays remarkably decrease in the two configurations $TXOP-1$ and $TXOP-2$; in fact, by using only the APP mechanism, the maximum delay obtained under the same kind of conditions (e.g., 7 QSTAs) is about to $200ms$ whereas in the two new cases it reaches at maximum $100ms$ (compare Figure 5(a) with Figure 6). It is to be noticed that the simple TOD mechanism (curves are marked as $TXOP-3$ in the Figure) is not sufficient to efficiently reduce the unfairness and the delays (the maximum delay we measure by adopting this scheme is about to $500ms$ in downlink). From these two Figures it can be also noticed that the results measured with the two configurations $TXOP-1$ and the $TXOP-2$ are quite similar. This means that, as noticed before, on one side the *TxOpLimit* differentiation improves the performance, on the other side this can be archived by simply doubling the *TxOpLimit* of the AP without necessarily adopting the maximum value.

Figures 8 and 9 illustrate the delay and the throughput curves for an AC2 traffic flow. By examining these curves, it is quite evident that, for this Access Category, the unfairness is reduced only when the $TXOP-1$ values are adopted. We recall that in $TXOP-1$ the *TxOpLimit* for the AP has been fixed to the maximum value: $6016\mu s$. On the contrary, with this configuration, the uplink flows experience higher delays compared to the Figure 5(b), since the *TxOpLimit* for the QSTAs is lowered from $6016\mu s$ to $3264\mu s$.

IV. Conclusions

Quality of service support in the 802.11 is a fast evolving field, driven by the need of satisfying different applications that will use the WLANs. This evolution is determining the definition of a new standard (named 802.11e) that will be finalized in the 2005. Thanks to the new HCCA and EDCA mechanisms stations supporting delay bounded applications can be accomodated. Furthermore, several wireless stations using EDCA contention access rules can use different MAc parameters setting to access the medium with different priorities. This report showed the capabilities of the HCCA satisfy high demanding flows and also demonstrated that suitable configurations of the MAC parameters can be used to achieve fairness between uplink and downlink in the WLAN. In this latterr case the Access Point can be provided with an higher priority to access the medium compared with QSTAs, in contention mode. This allows a fair access to the medium when the Access Point has high traffic loads to be transmitted in the downlink. The combination of APP and TOD has been demonstrated a powerful mechanism to reduce unfairness while bringing significant advantages especially when, in a WLAN, the traffic load increases.

References

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