RTS-AC: Admission Control Method for IEEE 802.11e WLANs

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ABSTRACT

In wireless lan an important concern is channel utilization. IEEE 802.11e TGe propose transmission opportunity (TXOP) scheme with admission control method in which a staion is allowed to send a number of consecutive packets limited by the duration allocated and station accepts or rejects the flows on the basis of available resources. However its use is not optimize. In this paper an scheme is proposed to increase the system eficiency by using the remaining TXOP duration efficiently. The performance of the scheme is evaluated from simulation developed in NS2 simulator.

Keywords

Wireless local area network, recovered transmission opportunity, quality of service, admission control, IEEE 802.11e, HCF.

1. INTRODUCTION

Nowadays, Wireless Local Area Networks (WLANs) and in particular the IEEE 802.11 technology [1] gives wireless access to the Internet and support for data communication in both public (hotspots) and private areas. Therefore, the best effort service support provided by the legacy standard IEEE 802.11 seems sufficient to satisfy the requirements of these applications. However, the increasing popularity of new real time applications, like VoIP or IPTV streaming that are delay sensitive or require bandwidth guarantees, influenced on further development of IEEE 802.11 technology. Consequently, a Task Group, called "e", (TGe) was specifically formed by IEEE with the objective of defining QoS enhancements for IEEE 802.11 WLAN systems. The standardization efforts of TGe resulted in a new amendment to the standard that develops a new medium access control (MAC) protocol designed for efficient bandwidth sharing and QoS support known as IEEE 802.11e [2].

The extension of the legacy MAC, proposed by TGe, Introduces new mechanism called Hybrid Coordination Function (HCF). The HCF is suggested to operate with two access modes: Enhanced Distributed Channel Access (EDCA) and HCF Controlled Channel Access (HCCA) [1]. Both new operation techniques are compatible with the legacy IEEE 802.11 DCF and PCF schemes and provide different QoS provisioning methods.

For controlled channel access mechanisms, admission control is an important component for the provision of guaranteed QoS parameters. A simple admission control has already been presented as a reference for HCCA in a recent TGe draft [2], [3]. IEEE 802.11e TGe mainly concentrate on the performance of enhancement achieved by using the transmission opportunity scheme and admission control method. However, this algorithm is somewhat inefficient because it assigns transmission opportunities (TXOPs) to one QoS station (QSTA) in static way. The TXOP modifies the standard transmission procedure of IEEE 802.11 technology by allowing multiple packet transmission on single channel access. Accordingly, a station is allowed to send a number of consecutive packets limited by the duration of allocated TXOP. However, some inefficiency of TXOP scheme may be observed when, due to the lack of sufficient number of packets in a winning queue, packets less then TXOP duration is sent within assigned TXOP limit. Consequently, only some part of reserved time is used. Therefore, for take as much as possible advantage of the collision free and contention free transmission provided by TXOP we propose to use a method that dedicates the remaining TXOP time for the transmission of packets from real time application queues.

The rest of the paper is organized as follows: Section II summarizes the QoS mechanism proposed for IEEE 802.11 standard [1]. The comprehensive study of HCF sample scheduler and admission control unit is presented in Section III. Section IV follows with evaluation of proposed mechanism. Section V gives some simulation results done in ns2 to show improvement of the new scheme. Finally, conclusion is drawn in section VI.

2. IEEE 802.11E QOS MECHANISM

The IEEE 802.11e specifications, [1], address the limitations in QoS provision of the legacy standard. Within the new standard the access to the medium is controlled by the Hybrid Coordination Function (HCF) which defines two access modes: contention based (CP) called Enhanced Distributed Channel Access (EDCA) and contention free (CF) called HCF Controlled Channel Access (HCCA).

2.1 Enhanced Distributed Channel Access (EDCA)

The EDCA copes with QoS shortcomings of the Distributed Coordination Function (DCF) access mechanism of the legacy MAC as described in [2]. By means of the Access Categories (AC) concept, the proposed enhancements allow traffic differentiation between different classes and prioritization using a new independent Enhanced Distributed Channel Access Function (EDCAF). The EDCAF is an enhanced version of DCF with specific contention window and Inter Frame Space (IFS) times for different ACs. Each station supports four ACs with different QoS expectations (AC_VO for voice traffic, AC_VI for video traffic, AC_BE for best effort traffic and AC_BK for background traffic). In fact the ACs provides support for the delivery of traffic with up to eight user priorities (UP). Consequently, the incoming packets are mapped to corresponding AC depending on their QoS requirements as shown in Fig. 1 [3]. Prioritization in this access mode is reached by assigning different values of following contention parameters to each AC:

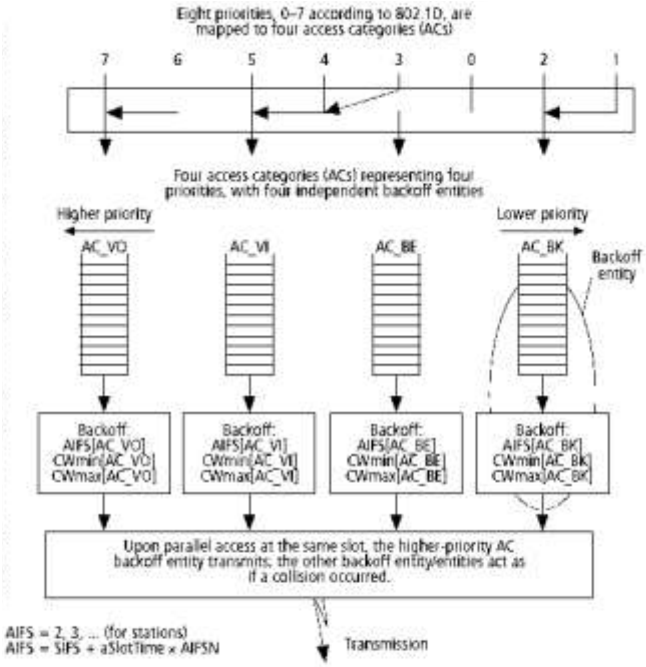

Fig. 1 EDCA mechanism

AIFS – Arbitration Interframe Space value defines the free time interval before the back-off stage. The value of AIFS may be changed by means of the Arbitration Interframe Space Number (AIFSN) and is given by equation (1). Smaller values of AIFS correspond to higher priority.

$$AIFS[AC] = SIFS + AIFSN[AC]*aSlotTime \qquad (1)$$

where SIFS (Short Interframe Spacing) and aSlotTime (slot time) are parameters known from the DCF mode. In the case of non-AP QoS aware stations (QSTA), the value of AIFSN[AC] should be equal or greater to 2, which corresponds to the DIFS interval of legacy MAC. However, for QoS aware AP (QAP) it should be equal or greater to 1, what can provide QAP with the highest priority.

CW – Contention Window provides the range of possible back-off values before starting the transmission. CW is defined by means of its minimum and maximum size. Then, selecting a CW value within a small maximum and minimum range provides at the AC with higher priority.

In contrast to the DCF contention parameters, the EDCAF ones are not dependent on the PHY layer and can be assigned dynamically by AP. Therefore, better traffic differentiation and prioritisation may be provided as shown in [3].

The main principles of the EDCA access are similar to those of the DCF. Each EDCAF represents a separate DIFS mechanism thus after detecting the medium idle for an AIFS time, a back-off deferral process take place and when reaches zero transmission begins. If in a given station, two or more EDCAFs finish their back-off at the same time instant, then the so called virtual collision take place. In such situation the EDCAF with the highest priority (AC) is allowed to transmit whereas lower priority ACs behave as if they experience a "collision" and thus they need to increment their CWmax range.

Another enhancement introduced by IEEE 802.11e standard copes with uncontrolled packet transmission time of the legacy stations' packets and is referred to as Transmission Opportunity (TXOP). The principle of TXOP mechanism is to allow, for the station that won the channel access, the transmission of multiple packets, within assigned time limit, separated by SIFS intervals. A TXOP can be obtained through contention in EDCA or be assigned by AP in HCCA.

2.2 HCF Controlled Channel Access (HCCA)

The polling mechanism of HCF is similar to the legacy PCF called HCCA. The HCCA uses a QoS-aware HC which is typically located at the AP in infrastructure WLANs. It gains control of the channel after sensing the channel is idel for a time period equivalent to a PCF interframe space (PIFS) interval. Thus, the HC can use the point coordinator's higher channel access priority to allocated TXOPs to wireless stations to transmit QoS data. In HCF, the HC is allowed to start contention-free burst at any time during the contention period after the medium remains idle for at least a PIFS interval. The contention-free burst is more flexible than legacy PCF because the later has a fixed length and must occur periodically after a beacon frame.

After grabbing the channel, the HC polls a QoS station on its polling list. In order to be included in the QoS polling table of HC, a QoS station must issue a QoS reservation by means of special QoS management action frames. A separate reservation must be made for each traffic straeam which is described by a TSPEC. QoS station may send TXOP requests during polled TXOPs ao EDCF TXOPs as well as during controlled contention intervals.

Upon receiving a poll, the polled station either responds with a QoS-NULL frame, if it has no packets to send; or it responds with a QoS-Data+QoS-ACK packet, if it has data to send. During a TXOP, the polled station may initiate multiple frame exchange sequences. This gives the HCF the flexibility to support bursty QoS traffic. At the end of a TXOP, the HC gains control of the channel again, and it either sends a QoS-Poll to the next QoS station on its polling list, or releases the channel if there are no more station to polled.

3. IEEE 802.11E SAMPLE SCHEDULER AND ADMISSION CONTROL UNIT

This section includes the reference design for a sample scheduler and admission control unit (ACU). In the scheduling of HCF, the QoS station (QSTA) requiring HCCA negotiates with QAP and creates a TSPEC which contain some QoS parameters of a traffic flow. The schedular uses mandatory set of TSPEC parameters to generate a schedule: Mean Data Rate (ρ, avaerage bit rate for transfer of the packets), Nominal MSDU Size (*L*, nominal size of the packets) and Maximum Service Interval (*SImax* maximum time allowed between the start of successive TXOPs allocated to the station) or Delay Bound *(D)*.

The scheduler chooses a number lower than the minimum of all Maximum Service Intervals for all admitted streams, which is a submultiples of the beacon interval. This value will be the Scheduled Service Interval *(SI)* for all wireless stations with admitted streams. In the reference design, the scheduler calculates the average number of packets that arrived at the

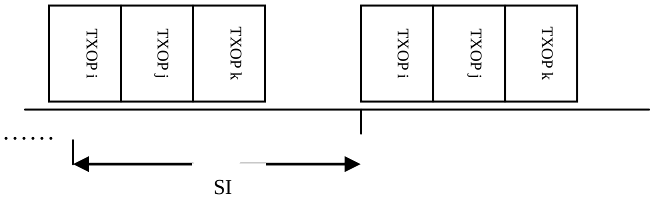

Fig. 2 TXOP allocation in reference scheme

Mean Data Rate during the *SI.* For the traffic flow *i* in a station, the average number of packets arrived during *SI:*

$$N_i = \left\lceil \frac{\rho_i . SI}{L_i} \right\rceil \qquad (2)$$

Then the scheduler calculates the TXOP duration as the maximum of (1) time to transmit N, frames at *R,* and (2) time to transmit one maximum-sized MSDU at &, which is the minimum TXOP duration allocated to flow *i* for transmitting one maximum-sized MSDU. The TXOP duration for flow *i:*

$$TD_i = \max\left(\frac{N_i . L_i}{R_i} + O, \frac{M_i}{R_i} + O \right) \qquad (3)$$

Ri is the Minimum Physical Transmission Rate in the TSPEC. If the TSPEC does not contain this parameter, the observed Physical Transmission Rate is used. *Mi* is Maximum MSDU size of flow *i. O* is the per-packet overheads of the packet transmission, including the transmission time for ACK frame, interframe space, MAC header, CRC overhead and the PHY PLCP Preamble and Header. The TXOP duration for a station is the sum of the TXOP duration of individual traffic stream of that station. The TXOP duration as described in [5] of station *j* with n traffic flows is:

$$TXOP_j = \sum_{i=1}^{n} TD_i + SIFS + t_{POLL} \qquad (4)$$

$SIFS + t_{POLL}$ is the per-station overhead which are the smallest interframe space and the transmission time of a CF-Poll frame.

When a new stream requests admission, the admission control process is done in three steps. First, the ACU calculates the number of MSDUs, using equation (2), that arrive at the mean data rate during the scheduled SI. Second, the ACU calculates the TXOP duration that needs to be allocated for the stream. The ACU uses the equation for $TXOP_i$ shown in (4). Assumed that there are admitted flows in *k* stations and a new flow arrived in $k+1^{th}$ station. Finally, the ACU determines that the stream can be admitted when the following condition is satisfied:

$$\frac{TXOP_{k+1}}{SI} + \sum_{i=1}^{K} \frac{TXOP_i}{SI} \le \frac{T - T_{CP}}{T} \qquad (5)$$

T : Length of super frame (beacon interval) in time.

T_{CP} : Length of contention period in time.

The TXOP option is advantageous because the contention overhead is shared between all the packets allocated within the burst. Therefore, higher efficiency and lower delays can be obtained, such as discussed in references [2]. The station ends its TXOP burst once it does not have more packets to be transmitted in the queue belonging to the winning AC, or when there is not enough free space for the next packet exchange (QoS Data + ACK) or when the packet transmission fails.

4. ADMISSION CONTROL USING RECOVERED TRANSMISSION OPPORTUNITY

This work specifically addresses one drawback of scheme: the static division of bandwidth. In [2], for each station, the TXOP duration is constant (static) and allocated by AP periodically, spaced by *SI* (Fig. 2). However, in HCF scheduling a station can waste the TXOP advantages when within a winning AC queue there are an insufficient number of packets to fill the assigned TXOP limit. Certainly, in that situation the station must end this TXOP burst once there are not more packets to be transmitted in the queue thus wasting the resting time within the won TXOP period. That results in a decrease of the effectiveness of the TXOP mechanism and admission control method thus reduction of the achievable maximum saturation throughput.

The proposed scheme is similar to the reference one with the changes for using remaining TXOP duration, we called the scheme as recovered transmission opportunity based scheme for admission control.

For the simplicity, the ACU of the reference scheduler described in previous section is divided into two admission control unit as ACU1 and ACU2. ACU1 works in the same way as original ACU of the reference scheduler does i.e. it calculates the number of MSDU as shown in equation (2) and then calculates the TXOP duration as shown in equation (3). As it is stated that because of insufficient number of packets within the winning AC queue to fill the TXOP duration the station must ends this TXOP burst once there are not more packets to be transmitted thus wasting the resting time within the won TXOP period so, ACU2 is introduced in the proposed scheme to take advantage of remaining TXOP duration (TXOP_remain) for enhancing the system efficiency in term of throughput, packet-loss and mean delay.

The buffered queue length of each access category at each QSTA, which is transmitted to QAP, through the queuesize sub-field of the QoS Control field in the MAC header. We can calculate the remaining TXOP using buffered queue length and queue monitoring process. So, after calculating TXOP_remain it sends back to the ACU2 for TXOP allocation to new flows as follows:

$$\frac{TXOP_{k+1}}{SI} + \sum_{i=1}^{K} \frac{TXOP_i}{SI} \le \frac{T - T_{CP}}{T} + TXOP\_remain \qquad (6)$$

So, adding the remaining TXOP duration with $\frac{T - T_{CP}}{T}$ entity may enough to transmit more packets. So, the packet loss rate may be reduced. Thus, some channel capacity can be saved to admit more flow. This section will present an algorithm for remaining TXOP duration arrangement. The proposed Admission Control method has following steps:

1: the number of MSDU that arrived();
/* the number of MSDU that arrived at the mean data rate during the SI $N_i = \left\lceil \frac{\rho_i . SI}{L_i} \right\rceil$ */

2: calculate the TXOP
/* time to transmit Ni frames at Ri and time to transmit one maximum size MSDU at Ri (plus overheads):

$$TD_i = \max\left(\frac{N_i . M_i i}{Ri} + O, \frac{M \max}{Ri} + O \right) \quad */$$

However, the sample scheduler and its admission control method [2] do static TXOP generation and based on that there is an admission control method. Thus, if number of packets (pl) in an winning AC queue is less then won TXOP duration so remaining TXOP duration goes waste. So, some criteria are added to sample scheduler to achieve what we need.

3: calculate packet length(pl);

4: calculate TXOP_remain;

/* $TXOP\_remain = TXOP[i] - pl$ */

```
if TXOP_remain is Zero then
    for Each New Flow do
        TXOPk+1 is the TXOP required for new flow and TXOPi is the sum TXOP's of all admitted flows
        $\frac{TXOP_{k+1}}{SI} + \sum_{i=1}^{K} \frac{TXOP_i}{SI} \le \frac{T - T_{CP}}{T}$
    end for
else
    for Each New Flow do
        $\frac{TXOP_{k+1}}{SI} + \sum_{i=1}^{K} \frac{TXOP_i}{SI} \le \frac{T - T_{CP}}{T} + TXOP\_remain$
    end for
```

The above algorithm ensures that remaining TXOP duration will get properly used for effective bandwidth utilization. So, it may enough to transmit more packets thus packet loss rate reduced and mean delay also become less we describe in the graph in the next section.

5. RESULTS AND DISCUSSIONS

In this section, two kinds of simulation topologies are used to show the improvement of the proposed scheme. The first one contains 18 mobile QSTAs and 1 QAP with only one TS per QSTA. The second topology is composed of 6 QSTAs and 1 QAP, each one with three different priorities TSs. For all the simulations, the destination of all the flows is the QAP (which is node 0 in our case): This allows us to compare fairly end-to-end delays among the different flows. PHY and MAC parameters are summarized in Table I.

Table 1. PHY and MAC parameters

Parameters	Value
SIFS	16µs
DIFS	34µs
Slot Time	9µs
CCA Time	3µs
Beacon Interval	500ms
PHY Rate	54 Mb/s
Min. bandwidth	24 Mb/s
MAC header	38 bytes
PLCP header	4 bits
Preamble Length	20 bits

5.1 Scenario 1

In the first scenario, six QSTAs send a high priority on-off audio traffic (64kbps), six others QSTAs send a VBR video traffic (200kbps of average sending rate) with medium priority and the remaining six QSTAs send a CBR MPEG4 video traffic (3.2Mbps) with low priority. Table II summarizes the different traffics used for this simulation.

Table 2. Description of the different Traffic Streams

Node	Application	Arrival Period (ms)	Packet size (bytes)	Schedulig rate (kbps)
1- 6	Audio	4.7	160	64
7-12	VBR video	26	660	=200
13-18	MPEG4 video	2	800	3200

Throughput curves on Figure 3 show that both RTS-AC and the standard HCF schemes (reference method) succeed in providing the required throughputs for all the flows. The schemes hardly differ in their throughput characteristics.

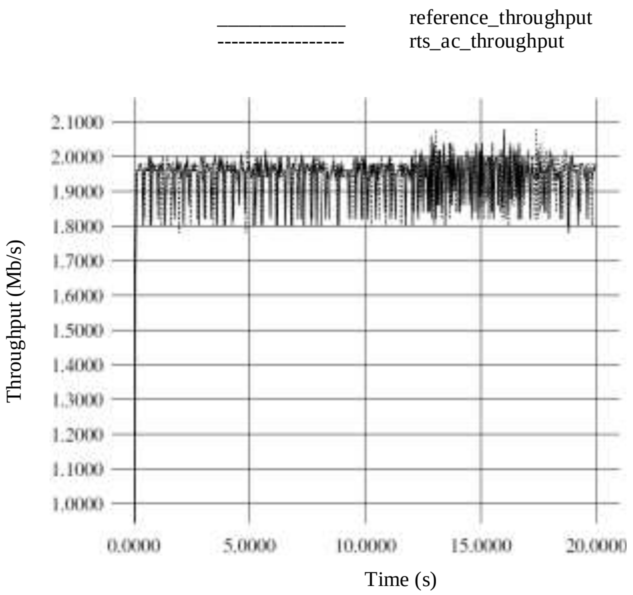

Fig. 3 Throughput Vs Time Characteristic

Figure 4 shows the standard HCF scheme, the delays of the flow are completely uncontrolled because the queue lengths are increasing during time. Please notice that in this work, packets are considered as lost only when reaching the maximum queue length limit and hence dropped by the queue buffers. Packet loss of RTS-AC scheme is less than standard HCF scheme. In the example of flows, the gain with RTS-AC is between 14% and 37% depending on the flow that audio traffic hardly experienced any packet losses and this can be observe from the Figure 4.

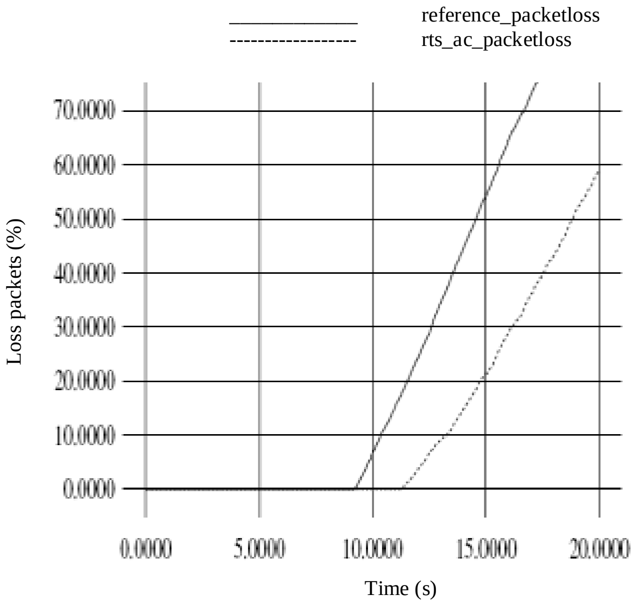

Fig. 4 Audio flow packet-loss characteristic

5.2 Scenario 2

In the second scenario, each QSTA sends three audio, VBR H.261 and CBR MPEG4 video flows simultaneously through three different MAC-layer priority classes. This topology aims at evaluating the behaviours of the different TSs in the same QSTA and with the same priority TS in different QSTAs in term of delay.

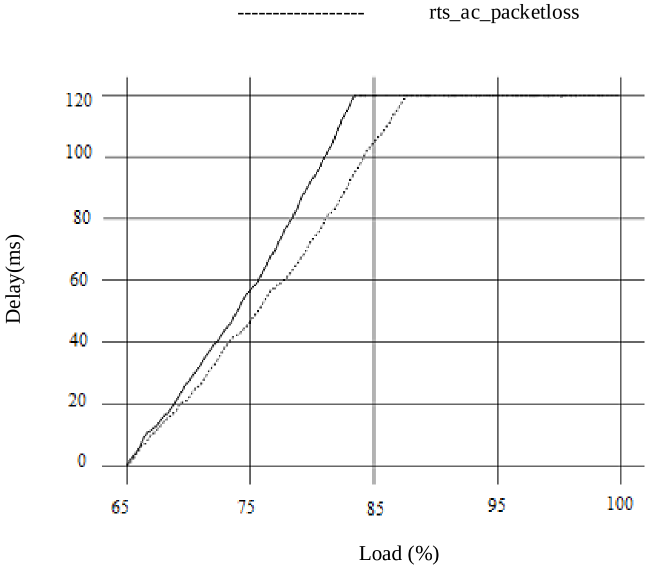

Fig. 5 Audio flow delay characteristic

Figure 5, shows the mean delays and the fairness of flows obtained with the both schemes for the network. The delays of flows with the standard HCF scheme are very high as compare to RTS-AC scheme.

It is shown from the different scenario that the RTS-AC scheme better utilizes the remaining TXOP duration for audio flow than standard HCF scheme.

6. CONCLUSIONS

In this paper, we extend the admission control algorithm in [2] to improve efficiency to admit more traffic flows. In this work the performance of admission control based on the IEEE 802.11e standard has been evaluated. It has been shown that admission control is necessary to support real time traffic and it also gives an overview of the features that can be used to support admission control in IEEE 802.11e standard.The algorithm is based on the sample scheduler and ACU. Thus, the TXOP durations are determined by the method in [2] to meet the requirement of stations.

The simulation results have shown that TXOP reservation and attention to load in the network are necessary. RTS-AC is able to achieve significant improvement in the channel utilization while guaranteeing the QoS to the real time traffic simultaneously.

The best thing about RTS-AC is that it strictly follows IEEE 802.11e with minimal overheads. RTS-AC is also compatible with schemes adapting EDCA parameters. The gain with RTS-AC is between 14% and 37% depending on the flow.

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