Contention Window Analysis and Proposed Algorithm for Collision Minimization of IEEE 802.11e EDCA

A. S. M. Tariq and K. Perveen

***Abstract*—The Enhanced Distributed Channel Access (EDCA) is introduced to provide QoS on the basis of Distributed Coordination Function (DCF) in IEEE802.11. The access mechanism of IEEE802.11e, referred to as EDCA, assigns different access categories (AC) with different types of data traffic based on priorities. Each priority uses a different set of medium access parameters to introduce QoS support. This led to the introduction of the principle of the virtual collision among stations also among access categories. The virtual collision occurs mainly due to same independent backoff value within the station or with other stations. In this paper, the effect of the virtual collision management of EDCA is presented on its fairness among other properties. Moreover, we proposed to enhance the EDCF performance with the fine tuning of the minimum contention window along with the AIFSN (Arbitration Interframe Space Number) value that depends on the traffic load.**

***Index Terms*— Wireless local area networks, contention window, collision, IEEE 802.11e, EDCF.**

I. Introduction

IEEE 802.11 Wireless Local Area Network (WLAN) is now extensively organized wireless network technologies in the world. IEEE 802.11 mainly is in debt to its cost effectiveness, easy deployment and high data transmission rates. However, 802.11 MAC (Medium Access Control) algorithms and the physical (PHY) layer are not supported with increasing popularity of multimedia applications, which require certain level of quality of service (QoS) guarantees in terms of consistent, in time and reliable data transfer. Therefore, an enhanced version IEEE 802.11e is introduced, which is based on service differentiation and supports QoS requirements for user perspective [1].

The work is organized as follows: Section II provides brief introduction Quality of Service (QoS) and limitation of IEEE802.11. Section III is the overview of IEEE 802.11e MAC protocol. Section IV introduces the collision mechanism. Section V presents the importance of collision management. Section VI describes the proposed algorithms and Section V concludes the paper with future work.

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II. QoS and Limitations of IEEE 802.11

In term of qualitative and quantitative characteristics Quality of Service (QoS) refers throughput, packet loss, delay, and jitter and bandwidth utilization over a network. QoS can be seen from the network or application point of view. It is said to support QoS, certain QoS requirements of application and the network capable of fulfilling these requirements. QoS requirements vary from application to application and can be classified in three dimensions: bandwidth, delay, and data loss [2]. IEEE 802.11 MAC protocol does not make any guarantees about delay, bandwidth and packet loss. It serves all types of applications in the same manner, without be aware of what QoS requirements an application may have. There is no support for service differentiation. Bandwidth, delay and loss-sensitive applications are served in the same way, on the best-effort basis. As a result, all types of data traffic suffer from same amounts of delays, losses and variations in bandwidth as the network becomes congested. Therefore, IEEE 802.11e supports quality of service by introducing priority mechanism. All types of data traffic are not treated equally as it is done in the original standard, instead, 802.11e supports service differentiation by assigning data traffic with different priorities based on their QoS requirements.

III. IEEE802.11E

A. Overview

IEEE 802.11e is the enhanced version of the IEEE 802.11 MAC that is dedicated to provide Quality of Service. It supports QoS by the service differentiation and prioritization mechanism. Different data traffic has different priority based on the QoS requirements. Basically, applications are divided into four Access Categories (AC) [2], [9]. Every frame with a specific priority of data traffic is then assigned to one of these access categories. For each AC, service differentiation is defined by utilizing a different set of contention parameters to get the medium access.

B. HCF and EDCF

HCF is the centralized coordination function that com-bines the features of Distributed medium access like DCF (Distributed coordination function) and centrally controlled medium access like PCF (Point coordination function) with improved QoS techniques. HCF defines two types of access mechanisms, The distributed contention-based channel access mechanism is called EDCA (Enhanced Distributed Channel Access) and the centrally controlled contention free access mechanism is called HCCA (HCF Controlled Channel Access) [3], [5], [10].

The EDCA defines multiple ACs with AC-specific Contention Window (CW) sizes, Arbitration Interframe Space (AIFS) values, and Transmit Opportunity (TXOP) limits to support MAC-level QoS and prioritization [1]. Every station has four independent EDCAFs, AC's range from 0 – best effort (AC_0), 1- background (AC_1), 2 – video (AC_2) and 3 – voice (AC_3). AC with highest priority has smaller CW so that the highest priority traffic can be benefited more than lower one. The CW is determined from the range of CWmin [AC] and CWmax [AC] Also, different Interframe space (IFS) is induced according to different ACs. Transmission begins if the channel is sensed idle in EDCF, otherwise the stations executes a back-off procedure after waiting a period of AIFS [AC]. Random Backoff value is determined from CW range. In other words, the back-off time is drawn from the interval [1, CW [AC] +1]. Each AC within a single station behaves like a virtual station that can independently start transmission if the channel is idle. AIFSN refers to length of the AIFS [2].

C. *Timing Relationship of EDCA*

Fig. 1 shows the enhanced distributed coordination channel access functions. To achieve service differentiation, instead of using fixed DIFS (Distributed Interframe Space, as described in 802.11 DCF), EDCA assigns higher priority ACs with smaller CWmin, CWmax, and AIFS to influence the successful transmission probability (statistically) [7]. The AC with the smallest AIFS has the highest priority, and a station needs to defer for its corresponding AIFS interval. The smaller the parameter values (AIFS, CWmin and CWmax) the greater the probability of gaining access to the medium [2]. Individual virtual station contends for access to the medium and independently starts its back-off procedure after detecting the channel being idle for at least an AIFS period. The back-off procedure of each AC is the same as that of DCF.

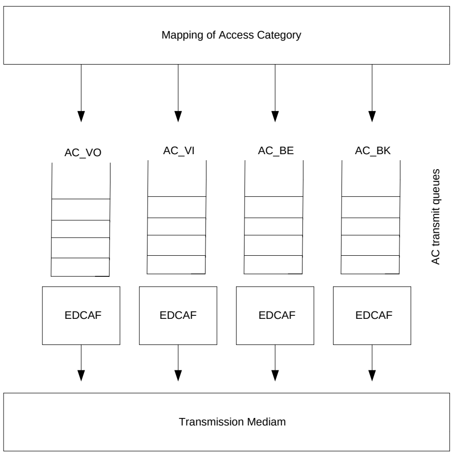

Figure 1. EDCA AC transmit queues

IEEE 802.11e EDCA defines a time interval in which a particular station can initiate transmissions called trans-mission opportunity limit (TXOPlimit) [7]. During this period, stations are allowed to transmit multiple data frames from the same access categories (ACs) continuously within the time limit defined by TXOPlimit. In 802.11e EDCA the higher priority ACs have a longer TXOPlimit, while lower priority ACs have a shorter TXOPlimit. Priority differentiation used by EDCA ensures better service to high priority class while offering a minimum service for low priority traffic. This mechanism improves the quality of service of real-time traffic. The preferred values of each access categories (ACs) access mechanism parameters that the standard recommends are presented [2] (see Table I) where CWmin=31 and CWmax=1023.The performance obtained is not being optimal since EDCA parameters cannot be adapted according to the network conditions [9]. Minimization of different access categories traffic impacts during transmission which occurred by high traffic load could be challenges.

TABLE I
CW AND AIFSN FOR DIFFERENT ACS.

AC	CWmin[AC]	CWmax[AC]	AIFSN
0	CWmin	CWmax	7
1	CWmin	CWmax	3
2	(CWmin+1)/2-1	CWmax	2
3	(CWmin+1)/4-1	(CWmin+1)/2-1	2

EDCA standard parameters are selected for simulation scenario 1.

IV. EDCA COLLISIONS

Higher priority ACs has small contention window that is the reason they suffer from higher collisions. Two types of collision can be experienced [8].

A. *Internal collision*

Every AC in the single station can act as a virtual station and transmit whenever channel is idle. When more than one EDCAF in the same station count their back-off timers to zero and try to transmit at the same time, it leads to a situation referred to as internal collision or virtual collision. In such situation, the access to the medium is granted to the EDCAF for the highest priority AC among the colliding EDCAFs, and the lower priority colliding EDCAF doubles its Contention Window and back-off, similar to an external collision.

B. *External collision*

An external collision occurs if back-off timers of the EDCAFs at two or more stations reach zero at the same time and win access to the medium. After the external collision the colliding EDCAFs double their Contention Windows as original standard and choose new back-off values, and the rest of the EDCAFs retain their paused back-off timers.

V. COLLISION MINIMIZATION

Collision will minimize with proper adjustment of CW according to access categories. Adjustment mechanism for contention window and AIFSN should be finely tuned when collision rate and traffic load is high. Dynamically adjusting the contention window minimizes the internal and external collision of IEEE 802.11e [3].

The performance of IEEE 802.11e's EDCA mechanism has been extensively investigated during last few years with little paid attention to the collision management. For this purpose, here we focused on internal and external collision minimization that has a manifest impact on the service differentiation of EDCA with highlighted the inefficiency of EDCA in handling collisions and to propose an efficient algorithm as well as modification of EDCA without simulation that might improves fairness and throughput.

VI. Proposed Algorithm For Contention Window Adjustment

We proposed a collision minimization process which is not being simulated but logically it should minimize the overall collision. The minimization process is designed according to both contention window and AIFSN scheme. We focused on collision reduction and appropriate service differentiation according to collision rate (CR), Traffic load (TL), AIFSN which indicates fine tuning of contention window (FTCW). We propose the mechanism as the following behavior:

f_{CR}^{i} : *Collision Rate in* i^{th} *station at a interval q*
f_{CRTh}^{i} : *Collision Rate threshold, minimum collision that does not dramatically changes overall collision.*
CW_{new}^{i} : *New contention window in* i^{th} *station*
$CW_{new}^{i}[AC_H]$: *New contention window for higher priority level in* i^{th} *station (AC_3 and AC_2)*
$CW_{new}^{i}[AC_L]$: *New contention window for higher priority level in* i^{th} *station (AC_0 and AC_1)*
AIFS range: $AIFSN_{max}^{i}[AC_{H,L}]$ *equal to* 7 *and* $AIFSN_{min}^{i}$ *equal to* 1.
PF_{new} : *New persistence factor value depends on CR and TL*
TL_{TH} : *Threshold traffic load, approximate parameter that depends on the collision rate and number of stations.*

If collision occurs and $f_{CR}^{i} > f_{CRTh}^{i}$ *then*

$CW_{new}^{i}[AC_H] = CW_{max}^{i}$ *[AC_VI]*

$CW_{new}^{i} = PF_{new} \times (CW_{old}^{i}[AC_L] + 1) - 1$

if $TL > TL_{th}$ *then*

$AIFSN_{new}^{i}[AC_{H,L}] = AIFSN_{max}^{i}[AC_{H,L}]$

else

$AIFSN_{new}^{i}[AC_{H,L}] = AIFSN_{min}^{i}[AC_{H,L}]$

endif

else

CW_{new}^{i}, $AIFSN^{i}[AC_{H,L}]$ *and* CW_{max}^{i} *are set to be default values.*

endif

A. Discussion

The simulation of this proposed algorithm is out of the scope but we tried to approximate the size of contention window without simulation. The collision rate is equal to the ratio between number of collisions and number of data sent in an interval q. When collision occurs and CR is larger than the threshold (the threshold should be set according to previous experimental value), then the new contention window of ACH will be set to the maximum CW size of the AC_2. This mechanism depends upon CR and set the CW of ACL according to the value of new persistence factor and old CW size. The new PF parameter will change according to CR and TL but its minimum value is two. Also, we include the AIFS mechanism, when the TL is larger than the threshold; the new AIFSN will be set to the max (AIFSN) and vice versa. If no collision or CR is acceptable or less than threshold then both the CW and AIFSN mechanism value should be set as default.

B. Modification for internal collision minimization

Usual behavior of 802.11e MAC after the internal collision, low priority doubles its Contention Window and chooses a new backoff value, and the higher priority AC, starts the transmission without any backoff. This explains that the traffic of higher priority AC does not concern about collisions, it becomes out from additional delays after internal collisions, although it may starve the lower priority AC even more, i.e., it will take long time for low priority AC to count its new backoff to zero which becomes worse if AC_BK collides; it will hardly be able to decrement its backoff timer after higher priority ACs will have transmitted dozens of frames. To solve this fairness problem, additional proposed modification may take important role described below. This solution might solve fairness problem among ACs within same stations which tends to minimization of internal collision.

if collision occurs Define CR of colliding ACs except high priority collied AC_i.
CR_{AC_i}: *Collision rate of* AC_i *where* $i = 0 \ldots .3$
$CW_{new}[AC_i] = CW_{max}[AC_i] + (CR_{AC_i} \times CW_{max}[AC_i]$

C. Modification for External collision minimization

As in above, external collision occurs if backoff timers of the ACs at two or more stations accidentally get the same backoff values or reach zero backoff value Analogous to the original Standard, after the external collision the colliding ACs double their Contention Windows and choose new backoff values, and other ACs start their timers. In other words, start decrementing the newly chosen backoff values while other EDCAFs in both stations continue to decrement their paused backoff timers. This tends to unfair for both station with high Contention Window, which becomes low traffic transmission probability. Due to the fact of avoid collision we should concern about Contention Window size based on their last collision rate log file. This will allow guaranteeing a complete fairness among the access categories among stations while still having active collision avoidance mechanisms. This following theoretical solution might minimize external collision probabilities that can be implemented using simulation tool.

if collision occurs Define CR of colliding ACs CheckPriority among stations
if collision occurs with same priority level
$CW_{new}^{s}[AC_i] = CW_{max}^{s}[AC_i] + (CR_{AC_i}^{s} \times CW_{max}^{s})$
$CR_{AC_i}^{s}$: *Collision rate of* AC_i^{s}
where priority level, $i = 0 \ldots .3$ *and Station,* $s = 1,2 \ldots ..n$
if collision occurs with different priority level with different stations
higher Priority at station s now set
$CW_{new}^{s}[AC_H] = (CW_{max}^{s}[AC_H] + CR_{AC_H}^{s} + CR_{AC_H}^{s_{internal}}) \times PF_H^{s}$
Lower Priority at station s now set
$CW_{new}^{s}[AC_L] = (CW_{max}^{s}[AC_L] + CR_{AC_L}^{s} + CR_{AC_L}^{s_{internal}}) \times PF_L^{s}$

VII. Conclusion And Future Work

In this paper, we focused on the CW size so that it will increase according to Traffic load and collision rate. We have also proposed a CW adjustment mechanism named the fine tuned contention window (FTCW), this will minimize the internal and external collision among different access categories. Moreover, we modified this algorithm concerning with internal and external collision. Due to a fixed CW size of AC_H when collision occurs and larger than the CR threshold, this will satisfy logically that CW of AC_H will be high and collision of AC_H will be minimized. Also, we include the threshold (Traffic load) based AIFSN value which will add an advantage over higher traffic of $AC_{H,L}$. This becomes logically satisfies the minimization of overall collision. In future it can be simulated by using any of the network simulation software (GloMoSim, OPNET, ns2).

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