PERFORMANCE ANALYSIS OF IEEE 802.11E EDCA WITH QOS ENHANCEMENTS THROUGH ADAPTING AIFSN PARAMETER

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ABSTRACT

Enhanced Distributed Channel Access is a priority mechanism which supports access category (AC) wise QoS by differentiating initial contention window (CW) size and arbitration inter-frame space (AIFS) time. EDCA has fixed range of CW and AIFS that has been chosen initially. In contemporary EDCA model AIFS parameter for each AC remains static, irrespective of number of stations in a network. We propose a scheme where we vary AIFS time of each access category, depending on current congestion on network. The proposed model incorporates a mechanism where AIFS wait is smaller if there are fewer stations contending and moves to more AIFS wait time in case of many stations willing to transmit. Simulations are also conducted to validate our suggested enhancements for AIFSN parameter.

KEYWORDS: *Enhanced Distributed Channel Access (EDCA), Access Category (AC), Arbitration Interframe Spacing Number (AIFSN), Contention Window (CW)*

I. INTRODUCTION

IEEE 802.11 [6] WLAN is a widely used, robust, scalable communication network which transmits information over wireless links. It is a protocol for best effort service designed to work in two modes.

Distributed Coordination Function (DCF) [6] employs carrier sense multiple access with collision avoidance (CSMA/CA) with binary back-off for asynchronous data transmission.

Point Coordination Function (PCF) [6] is optional mechanism and uses a centrally controlled channel access mechanism to support time-sensitive traffic flows. PCF has not been implemented in most current products.

With evolving customer needs like requirement of video/audio streaming, wireless phone over IP, real-time applications Quality of Service (QoS) is particularly important. DCF doesn't provide QoS, PCF not being widely implemented and these applications do not differentiate between different data streams with different QoS requirements. To support such applications the IEEE 802.11e [5] MAC employs contention based channel access EDCA and centrally controlled channel access function Hybrid Coordination Function (HCF).

This paper has been organised in five sections. We discuss legacy DCF and EDCA models for contention and transmission in Wireless LANs in sections II, III. In section IV we propose an adaptive model which will react according to present load conditions in the network by attuning AIFS parameter. Section V studies simulation results of the proposed scheme.

II. DISTRIBUTED COORDINATION FUNCTION

2.1. The Basic Access Mechanism [6]

A station (ST) with a new frame to transmit monitors the channel activity. When the channel is idle for distributed interframe space(DIFS) period, it backs-off for random number of slots. The backoff counter is frozen, if during backoff the medium is sensed busy. When the medium is free; the backoff counter resumes and ST transmits when the backoff counter reaches zero. Otherwise, if the channel is sensed busy (either immediately or during the DIFS), the station persistently monitors the channel until it is measured idle for DIFS time. ST generates the random backoff interval before transmitting to avoid collision with frames being transmitted by other stations. To evade channel capture, ST waits a random backoff time between two consecutive new frame transmissions, even if the medium is sensed idle in the DIFS time.

DCF employs a discrete-time backoff scale. The time immediately following an idle DIFS is slotted, and a station is allowed to transmit only at the beginning of each slot time (size σ). Slot time is set to the time needed at any station to detect the transmission from any other station.

The back off procedure is exponential. During each transmission, the backoff time is uniformly chosen in the range (0, w-1) where w is called the contention window, and depends on the number of failed transmissions for the packet. At the first transmission attempt, w is initialized to CW_{min} (minimum contention window). After each unsuccessful transmission, w is doubled, up to a maximum value $CW_{max} = 2^m CW_{min}$.

When the channel is sensed idle, the backoff time counter is decremented; "frozen", when a transmission is detected on the channel, and reactivated when the channel is sensed idle again for DIFS period. The station transmits when the backoff time reaches zero.

2.2. RTS/CTS Mechanism [6]

This is an optional four way handshake technique to avoid the hidden terminal problem. Hidden terminals are those stations which are sensing the channel for being idle but are far away from the sending/receiving channel. Since they cannot sense the channel activity (being at a distance), they transmit and hence resulting in collision. To address this problem the following mechanism is employed.

A station (ST) willing to transmit a frame, waits until the channel is sensed idle for a DIFS, and follows the backoff conditions, and transmits a special short frame called request to send (RTS) before sending the frame. When the receiving station (DST) detects an RTS frame, it responds, after a SIFS, with a clear to send (CTS) frame. ST transmits its frame only if it receives CTS frame correctly and CTS frames carry information of the length of the frame to be transmitted. This information can be read by any listening station, which can update its network allocation vector (NAV). NAV has information about the period of time when the channel will remain busy. Therefore, when a terminal is hidden from either the transmitting or the receiving station, by detecting just one frame among the RTS and CTS, it can delay further transmission accordingly, and thus avoid collision.

The RTS/CTS mechanism reduces the frames involved in contention process and hence is very effective in terms of system performance. If stations wanting to transmit at the same time employ the RTS/CTS mechanism, collision occurs only on the RTS frames, and it is detected easily by the transmitting stations by the lack of CTS responses making the system adapt accordingly.

III. ENHANCED DISTRIBUTED CHANNEL ACCESS[5]

DCF provides the best effort service and real-time multimedia applications (like voice, video) are not differentiated with data applications. EDCA is designed to enhance the DCF mechanism to provide prioritized QoS and to provide a distributed access method to support service differentiation among traffic classes. Traffic is categorised in four Access Categories (ACs). Smaller CWs are assigned to ACs with higher priorities so that probability of successful transmission is biased towards high-priority ACs. The initial CW size can be set differently for different priority ACs, yielding higher priority ACs with smaller.

Table 1. Contention Window Boundaries [5] for different ACs.

AC	CW_{min}[AC]	CW_{max}[AC]	AIFSN
0	CW_{min}	CW_{max}	7
1	CW_{min}	CW_{max}	3
2	$(CW_{min}+1)/2-1$	CW_{max}	2
3	$(CW_{min}+1)/4-1$	$(CW_{min}+1)/2-1$	2

Differentiation is achieved by applying AIFS wait instead of using fixed DIFS as in the DCF. The AIFS for a given AC is determined by the following equation:

AIFS = SIFS + AIFSN * slot time

AIFSN: AIFS Number and determined by the AC and physical settings

Slot time: Time slot duration.

Table 2. Default EDCA Parameters [5] for different ACs.

AC	CW_{min}[AC]	CW_{max}[AC]	AIFSN
AC_BK	15	1023	7
AC_BE	15	1023	3
AC_VI	7	15	2
AC_VO	3	7	2

The AC with the smallest AIFS has the highest priority. The physical carrier sensing and the virtual sensing methods are similar to those in the DCF. The countdown procedure when medium is sensed idle is different in EDCA. After the AIFS period, the backoff counter decreases by one at the beginning of the last slot of the AIFS. In DCF, this is done at the beginning of the first time slot interval following the DIFS period.

For each station, different ACs have different queues for buffering frames. Each AC within a station acts like a virtual station and contends for channel access. AC independently starts its backoff after sensing the medium idle for at least AIFS period. During virtual collision: different ACs finish AIFS wait simultaneously, the AC with higher priority has the opportunity for physical transmission, while the lower priority AC follows the backoff rules.

A transmission opportunity (TXOP) limit has been defined which is the time interval for a station when it can initiate transmissions. During a TXOP, a station may be allowed to transmit multiple data frames from the same AC with a SIFS wait between an ACK and next frame. This is also referred to as contention free burst (CFB).

IV. ADAPTING AIFSN PARAMETER IN EDCA

Joe Nauom Sawaya, Bissan Ghaddar in [1] and Joe Nauom Sawaya, Bissan Ghaddar and others in [3] suggest a scheme where based on current load conditions CW value is estimated and the system outputs CW value at which node will be able to transmit. However, the legacy EDCA, [1] and [3] and many other proposed adaptive models do not take into account the time each AC has to wait before transmitting. In EDCA, each access category has a fixed value of AIFSN using which it computes the AIFS time for which that access category must wait. The drawback of this scheme is that load conditions of the system are not taken into account. The load conditions include two main factors:

- Number of stations in the system
- Probability of collision

In this section we propose a scheme where AIFS wait time will vary according to the current congestion in the network. The system is assumed to be in condition where there are many stations contending for the slot and each station always has a frame to transmit. So the number of stations is an important part when load is being determined. The probability of collision determines the amount of congestion in the system at any time. It gives the number of frames that have to be retransmitted.

The stations must wait for a long time even when the load is less. In case the load is more the stations wait for a predefined time leading to more collisions. For example, if there are only 2 stations in the system and the AIFS for the access category with least priority is, say 7, it has to wait unnecessarily for a long time. This will only in increase the load as collisions would increase. To reduce the delay or number of collisions, depending on the system state, the AIFSN values may be adapted dynamically.

To have variable AIFSN values we define a range of values for each access category from which the actual AIFSN value is computed. We denote this computed AIFSN value by AIFSN'. The range of values for different access categories must be non-overlapping so that an access category with higher priority does not have to wait for a longer period than an access category with low priority. The selected value of AIFSN' lies at the lower end of the range if load is less, thereby selecting a smaller value. In case of greater load the value selected lies at the far end of the predefined interval. This results in stations having a smaller waiting time when load conditions are light and larger waiting time when the system is congested.

Let the range of values for each access category is denoted by [M_i, N_i]. For example, the interval could be [2, 5] for some access category. Thus the possible values from which the access category can choose its AIFN value lie in range 2 to 5. This range of values for each access category is predetermined depending on the optimal values that would be obtained after simulation. The AIFSN' values are chosen from amongst these values. The load condition is determined by the probability of collision at that time. We take P_c since it includes the no of stations in the system at any point of time as well as the amount of congestion in the system. We assume that each station always has a frame to transmit. Each time before transmitting a frame, the station must compute the collision probability P_c and the AIFSN' value to be used. The computation is illustrated as follows

Let the interval of values for access category i from which the $AIFSN_i'$ value will be chosen be [2, 5].

Let number of possible values to be chosen from be m_i

$m_i = 5-2+1 = 4$

The number of slots in which the probability of collision can be divided is thus 4.

The length of each slot is

$k_i = 100/4 = 25$

i.e. we have four slots from 0-25%, 25-50%, 50-75% and 75-100%

If the probability of collision lies in the first slot the AIFSN value 2 is chosen. Similarly if the collision probability lies in the range 50-75% AIFSN value 4 is chosen and so on.

Say the value of P_c is 0.3, then its quantified as 30%.

$AIFSN_i' = 2 + (0.3 \text{ X } 100) / 25$

$AIFS_i = SIFS + AIFSN'_i * \text{slot time}$

Generalising the above illustration

AIFSN range: [M_i, N_i]

The number of possible values AIFSN' can choose from is calculated as

$m_i = AIFSN[N_i-M_i+1]$ (1)

Let k_i denote slot length corresponding to m_i

$k_i = 100 / m_i$ (2)

We have a one to one correspondence between the possible P_c values and the AIFSN values to be chosen from. We choose that value of AIFSN which corresponds to the percentage slot that contains the current P_c value. This we can obtain by adding the minimum AIFSN value of the range of values to the corresponding slot of the probability.

$AIFSN_i' = minAIFSN_i + (P_c \text{X} 100)/ k_i$ (3)

Using this $AIFSN_i'$ we compute the $AIFS_i$ values.

V. SIMULATION ANALYSIS OF SUGGESTED MODEL

5.1. configuration

We used Pamvotis Network Simulator [8] (a free and open source simulator) to test various scenarios of dynamically adjusting AIFSN number. The source code of Pamvotis supports EDCA with static values of AIFS number for each category that can be configured during set up using GUI. We enhanced Pamvotis code with additional Java code to support AIFSN range which could be set-up before the simulation run. Our suggested mathematical formula using Equations 1, 2 and 3 was implemented to adapt AIFSN number depending on network congestion and many stations contending for a slot to transmit.

To achieve load condition, we have varied the number of stations in the system from 10 to 35 and data rate to be 2Mbps. Each station has a frame ready to send, with packet generation rate being constant and packet length (8000 bits) being uniform for all packets. Each simulation run was of 300 seconds. We had run simulations for various ranges for AIFS parameter. We discuss the scenario which reduced delay significantly.

Scenario 1: Classic EDCA

AC0 : AIFS [7-7], CW_{min} : 15 CW_{max}: 1023
AC1 : AIFS[3-3], CW_{min} : 15 CW_{max} : 1023
AC2 : AIFS[2-2], CW_{min} : 7 CW_{max} : 15
AC3 : AIFS[2-2], CW_{min} : 3 CW_{max} : 7

Scenario 2: Adapted EDCA

AC0 : AIFS [6-9], CW_{min} : 15 CW_{max}: 1023
AC1 : AIFS[3-6], CW_{min} : 15 CW_{max} : 1023
AC2 : AIFS[2-2], CW_{min} : 7 CW_{max} : 15
AC3 : AIFS[1-1], CW_{min} : 3 CW_{max} : 7

5.2. Analysis of Delay and Throughput Graphs

Pamvotis simulator randomly generates an Access Category for a station. We have calculated the mean delay for each AC for stations varying from 10 to 35.
Following are the mean delay graphs for each Access Category.

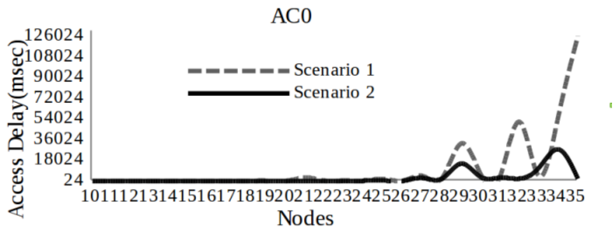

Figure 1. Delay Comparison (AC0)

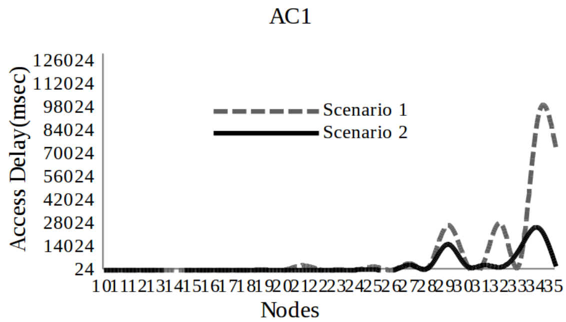

Figure 2. Delay Comparison (AC1)

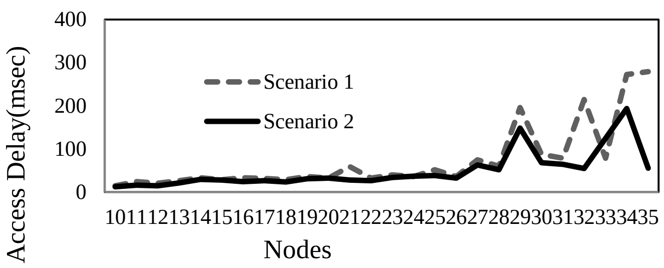

Figure 3. Delay Comparison (AC2)

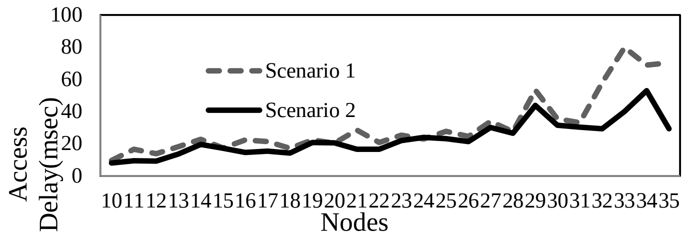

Figure 4. Delay Comparison (AC3)

In both the models, in accordance with service differentiation $Delay_{AC0}$ > $Delay_{AC1}$ > $Delay_{AC2}$ > $Delay_{AC3}$. As the number of stations increase the average delay per access category increases due to system load and collisions. We observe noticeable decrease in delay for Scenario 2 with range of AIFS parameters in comparison to fixed AIFSN in Scenario 1.

For throughput analysis we consider average throughput of each AC in both the scenarios, since Pamvotis generates ACs randomly. We then compare average throughput of the entire system from 10 to 35 nodes for the adapted and legacy EDCF model.

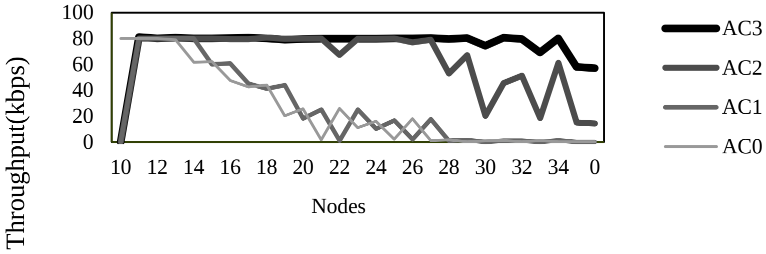

Figure 5. Scenario 1

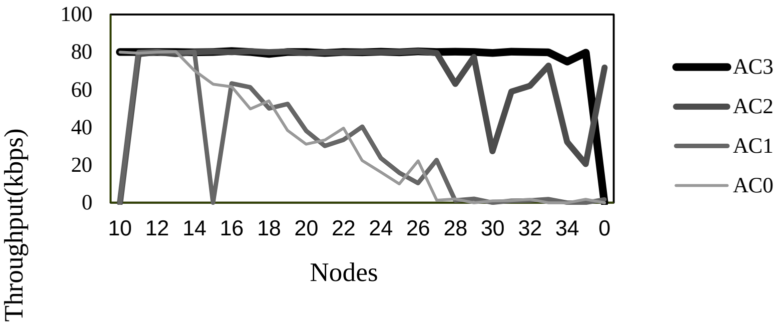

Figure 6. Scenario 2

We also see that the suggested model achieves service differentiation and $Throughput_{AC3}$ > $Throughput_{AC2}$ > $Throughput_{AC1}$ >= $Throughput_{AC0}$ where the access category is present.

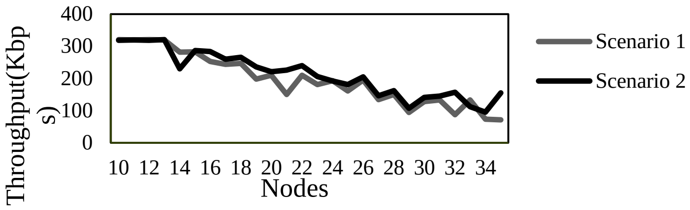

Figure 7. Average System Throughput

A marginal increase in average system throughput is also observed for Scenario 2.
Simulation results validate our model by maintaining service differentiation, showing a significant decline in delay for each AC and an increase in average system throughput.

VI. CONCLUSIONS AND FUTURE WORK

In this paper we had accustomed the AIFS parameter based on the load conditions in the system. The simulation results show improvement in system performance in terms noticeable decrease in media access delay and increase in throughput of each access category in comparison to the static AIFS values used in conventional EDCA algorithm.
Various scenarios were tested and we found through simulation that AC0**:** 6 – 9 AC1: 3 - 6
AC2: 2 – 2 and AC3: 1 – 1 are best suited for the model we proposed. We also conclude that using this range of AIFS parameters will continue to give higher priority to voice/video traffic and low priority ACs will not have to wait too long to transmit when there is less congestion in the system.
In future, it can be explored how adapting both CW[1] and AIFS on the network depending on current load conditions will improve the quality of service.

ACKNOWLEDGEMENTS

This work was a part of M.Sc. (C.S.) curriculum of Department of Computer Science, University of Delhi. The authors would like to thank Mr. Pradyot Kanti Hazra (Associate Professor,Deptt. of Comp, Sc., University of Delhi) for his valuable guidance.

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