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An Enhanced Scheduling Algorithm for Qos Optimization in 802.11e Based Networks

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Abstract - Quality of Service (QoS) is the ability to guarantee a certain level of performance to a data flow ie., guaranteeing required bit rate, delay, etc. IEEE 802.11 a/b/g networks do not provide QoS differentiation among multimedia traffic. QoS provisioning is one of the essential features in IEEE 802.11e. It uses Enhanced Distributed Channel Access (EDCA) which is a contention-based channel access mode to provide QoS differentiation. EDCA works with four Access Categories (AC). Differentiation of Access Categories are achieved by differentiating the Arbitration Inter-Frame Space (AIFS), the initial contention window size (CWmin), the maximum contention window size (CWmax) and the transmission opportunity (TXOP). However AIFS, CWmin, CWmax are considered to be fixed for a given AC, while TXOP may be varied. A TXOP is a time period when a station has the right to initiate transmissions onto the wireless medium. By varying the TXOP value among the ACs the QoS optimization- throughput stability and minimum delay is achieved. EDCA has many advantages such as it fully utilizes the channel bandwidth, and does not require centralized admission control and scheduling algorithms over the contention-free access mode.

Keywords : EDCA, MAC, IEEE 802.11e, Quality of Service, QoS optimization

GJCST Classification: C.2.1

AN ENHANCED SCHEDULING ALGORITHM FOR QOS OPTIMIZATION IN 802.11E BASED NETWORKS

Strictly as per the compliance and regulations of:

An Enhanced Scheduling Algorithm for Qos Optimization in 802.11e Based Networks

Ms.V.R.Azhaguramyaa [α], Prof.S.J.K.Jagadeesh Kumar [σ] & P.Parthasarathi [ρ]

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IndexTerms : EDCA, MAC, IEEE 802.11e, Quality of Service, QoS optimization

I. Introduction

a) Background

There have been various Frequency-based approaches are available for QoS optimization but they incur high computational complexity because modeling the AIFS, CWmin and CWmax values require solving non-linear equation systems that are extremely computationally demanding and not suitable for real-time applications. QoS optimization in contention-free mode requires centralized admission and scheduling algorithms, thus not flexible The Enhanced Distributed Channel Access mode is able to provide QoS optimization by easily controlling the TXOP.

b) IEEE 802.11e

IEEE 802.11e-2005 or 802.11e [3] is an approved amendment to the IEEE 802.11 standard that defines a set of Quality of Service enhancements for wireless LAN applications through modifications to the Media Access Control (MAC) layer.

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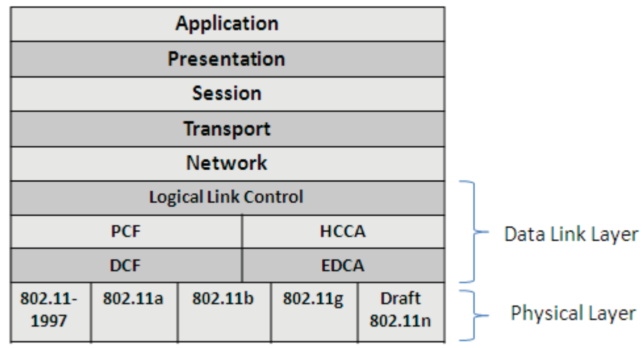

Fig. 1 OSI model of IEEE 802.11e

c) 802.11e MAC Operation

The 802.11e enhances the DCF and the PCF, through a new coordination function: the hybrid coordination function (HCF). Within the HCF, there are two methods of channel access, similar to those defined in the legacy 802.11 MAC: HCF Controlled Channel Access (HCCA) and Enhanced Distributed Channel Access (EDCA) which is illustrated in Fig. 1.Both EDCA and HCCA define Access Categories.

d) Importance of Access Categories in 802.11e

The 802.11e MAC supports the access categories which are listed in Table I.

Table I
Access categories

ACCESS CATEGORIES	DESCRIPTION
AC_VO(Voice)	Voice traffic and network control belong to AC_VO.
AC_VI(Video)	Video and video/controlled load belong to AC_VI.
AC_BE(Best Effort)	Best effort (E-mail) and video/excellent effort belong to AC_BE.
AC_BK(Background)	Background (Uninvited) traffic will come under AC_BK.

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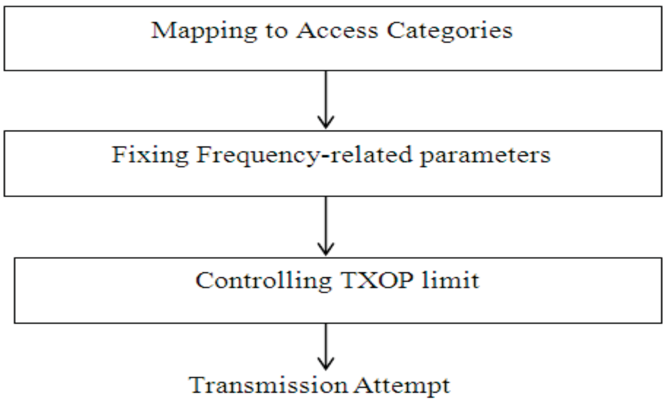

Fig. 2 QoS optimization process

e) Qos Optimization

Fig. 2 describes the process of QoS optimization. Initially heterogeneous traffic reaches the MAC and they are mapped to the corresponding Access Categories. Then all frequency-related parameters of various Access Categories are fixed, by controlling the TXOP Limit parameter the higher priority traffic has a higher chance of being sent and waits a little less before it sends its packet, on average, than a station with low priority traffic.

II. Related Work

Bellalta. B.*et al* investigated the basic values of EDCA parameters which should be changed to perform the QoS optimization [1]. Their work is mainly based on the frequency of acquiring transmission opportunities parameters and they have concentrated, to maximize the elastic (BE) throughput while assuring the bandwidth-delay requirements of the rigid flows(VO).

Zhen-ning, Kong *et al.* analyzed the performance of contention-based channel access in IEEE 802.11e [7] and they have produced the markov chain model of one Access Category per station. They have concentrated on AIFS in the Enhanced Distributed Channel Access.

In this paper we propose a new optimization algorithm which is the modification of EDCA and that new algorithm provides per stream QoS which is not available in EDCA [2] and it is achieved by tuning the duration of transmission opportunity parameter called TXOP limit.

This new work follows the implementation details outlined by, Khaled A. Shuaib. The author specified the cell structure of wireless networks, important parameters needed for creating the simula used in Qualnet simulation tool [5].

III. Proposed Scheme

a) EDCA

The Enhanced Distributed Channel Access (EDCA) mechanism of 802.11e extends the basic 802.11 DCF algorithm with Quality of Service capabilities. In EDCA mode, packets are categorized into prioritized classes, called access categories (ACs). In EDCA mode, airtime allocation among traffic sessions in different ACs is differentiated by assigning each AC with different EDCA parameters. Differential allocation of airtime to different ACs is essential for QoS-enabled applications.

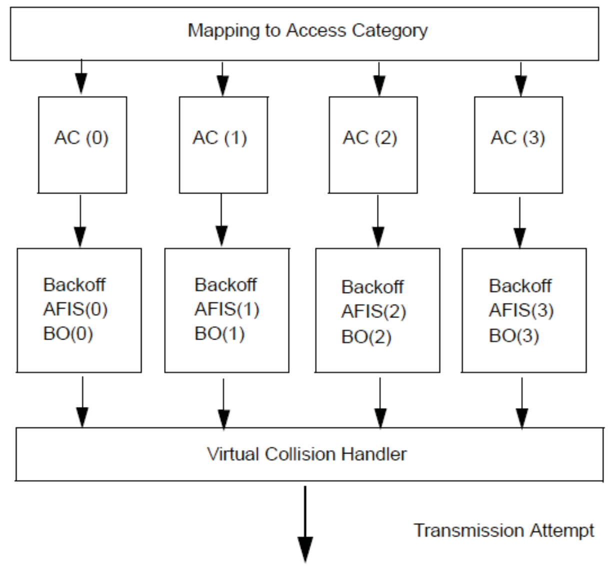

Fig. 3 EDCA

b) Edca Parameters

There are two sets of EDCA parameters that can achieve airtime differentiation.

1) Frequency of transmission opportunities: The frequency of transmission opportunities is determined through three parameters:

- Arbitration Inter Frame Space (*AIFS*)
- Minimum Contention Window Size (*CWmin*)
- Maximum Contention Window Size (*CWmax*)

Each AC maintains a contention window variable (CW), which is initialized to CWmin. The CW is incremented after transmission failures until it reaches CWmax, and is reset to CWmin after a successful transmission. To avoid collisions, a backoff timer is independently chosen from the range [0, CW] for each AC. Since smaller CWmin and CWmax generally lead to smaller CW values, they result in shorter backoff timer and higher transmission opportunity frequency.

2) Duration of transmission opportunity: The maximum allowed duration for each acquired transmission opportunity is determined by a parameter called, - *TXOP limit*.

Once a station acquires a transmission opportunity, it may transmit multiple frames within the assigned *TXOP* limit. Assigning different *TXOP* values to ACs, therefore, achieves differential airtime allocations

[2]. Controlling the TXOP limit allows us to derive a simple, closed-form equation for the effective airtime.

c) EDCA Mechanism

A new concept, transmission opportunity (TXOP), is introduced in IEEE 802.11e. A TXOP is a time period when a station has the right to initiate transmissions onto the wireless medium. A station cannot transmit a frame that extends beyond a TXOP. EDCA works with four Access Categories (ACs), as shown in Fig. 3, this differentiation is achieved through varying the amount of time; a station would sense the channel to be idle, and the length of the contention window for a backoff. Differentiated ACs is achieved by differentiating AIFS, the initial window size and the maximum window size. EDCA employs AIFS[i], CWmin[i], and CWmax[i] (all for i = 0... 3) instead of DIFS, minCW and maxCW, respectively [4].

d) QOS Optimization in IEEE 802.11e Using EDCA

Table III

Values of EDCA parameters

AC	AIFSN	TXOP (ms)	CWmin	CWmax
AC[0] - BK	7	0	CWmin	CWmax
AC[1] - BE	3	0	CWmin	CWmax
AC[2] - VI	2	6.016	CWmin/2	CWmin
AC[3] - VO	2	3.264	CWmin/4	CWmin/2

Each frame arriving at the MAC with a priority is mapped into an AC. The Table III specifies the values of EDCA parameters which belong to different access categories of IEEE 802.11e. AIFS for a given AC is determined by the following equation:

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

Where AIFSN is AIFS Number and aSlotTime is the duration of a time slot [1]. The AC with the smallest AIFS has the highest priority. The CWmin value is 31 and the CWmax value is 1023.

e) TXOP LIMIT- The Controlling Knob

Consider S wireless stations compete for the shared air medium of a wireless LAN using the IEEE 802.11e EDCA protocol. These wireless stations transmit data to/from the base station at different bit rates, and the rate differentiation is achieved by varying the TXOP limits for individual wireless stations. In optimization problem, it is a need to determine the total effective airtime (EA) of the wireless medium so that it can be divided among stations, and to avoid over/under allocation of the wireless medium. The virtual transmission time v_j as the time duration between the j-th and the (j + 1)-th successful transmissions is defined.

Each virtual transmission consists of three periods:

- Idle
- Collision
- Transmission

Let consider $E[x]$ to denote the average transmission opportunity limit for all wireless stations, and $E[v]$ to denote the average virtual transmission time. Then, the effective airtime can be given by:

$$EA = E[x]/E[v] \qquad (2)$$

Let denote the number of collisions in a virtual transmission time by C, define i_k to be the duration of the k-th idle period, and similarly, c_k to be the duration of the k-th collision period. Then $E[v]$ is given by:

$$E[v] = E[C](E[c] + t_d + t_s + t_a) + (E[C] + 1) E[i] + E[x] + t_d \qquad (3)$$

Where,

t_d is the distributed inter-frame space (DIFS),

t_s is the short inter-frame space (SIFS),

t_a is the average time of sending an acknowledgment.

From the equation (3) it is found that optimal solution for airtime differentiation comes from controlling the *TXOP* limit and by fixing the frequency of transmissions opportunities parameters.

IV. Experimental Results

Scenario consists of 1 Access Point and 24 wireless stations. Fig. 5 shows the simulation of created scenario and its progress. Scenario has the following properties [5]:

Simulation tool –QualNet 5.0.2
PHY Layer Model – IEEE 802.11b
Bandwidth – 20MHZ (min)
Antenna Height (PHY) – 1.5 meters
Terrain Space – 500*500 meters
Simulation time – 100 seconds
Scheduling algorithm used to select service classes – Strict Priority
Scheduling algorithm used inside the service class-FIFO.

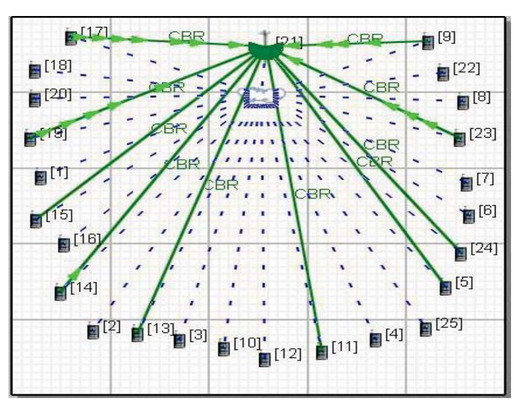

Fig. 5 Scenario Simulation

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a) Throughput analysis

Throughput is calculated for both Access point and wireless stations using the following formula:

Access Point

*Throughput= ((Total no. of bytes received * 8)/ Session Duration)*

Wireless Stations

*Throughput= ((Total no. of bytes sent * 8) / Session Duration)*

1) Access Point Throughput: Fig. 6 shows the throughput of server, the Access point node (21) is the server, throughput of 21 is very high because it always receives packets from the high priority traffic because of the TXOP variation. This result is taken from the statistics (.stat) file of created scenario.

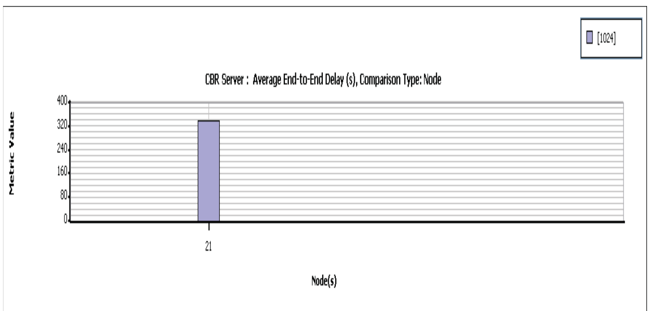

Fig. 6 Access point throughput analysis

2) Wireless stations Throughput: Fig. 7 shows the throughput of wireless stations which generates various traffic. The analysis says that the throughput of nodes which generates high priority traffic (9, 17, 19 and 23) is very high because of the TXOP variation.

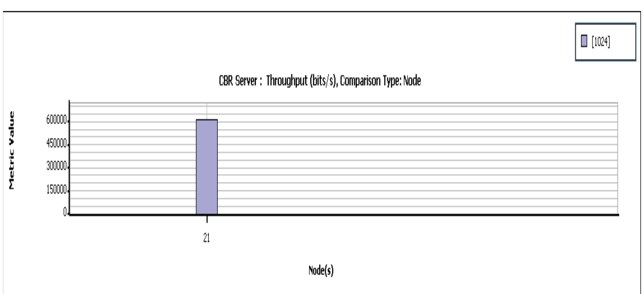

Fig. 7 Wireless stations throughput analysis

b) Average End-To-End Delay Analysis

Average end-to-end delay is calculated at the Access Point using the following formula.

CBR Avg. End-to-end delay = (Sum of the delays of each CBR packet received) / (no. of CBR packets received)

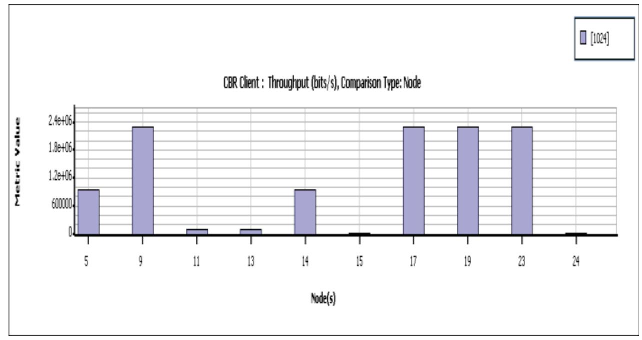

Fig. 8 Average End-to-End delay analysis

Fig. 8 shows the average end-to-end delay of the Access Point. From the statistics (.stat) file of created scenario, it is clear that the delay of high priority traffic is comparatively less than the low priority traffic.

V. Conclusion

The QoS optimization is provided by Enhanced Distributed Channel Access mode in IEEE 802.11e based Networks. With EDCA, packets are categorized into prioritized classes, higher priority traffic has a higher chance of being sent and waits a little less before it sends its packet, on average, than a station with low priority traffic. Using EDCA the quality improvement comes at negligible cost, because the optimal solution is computed using simple equations. EDCA is suited for networks which support link-layer traffic differentiation.

In future, the EDCA mechanism can be implemented for IEEE 802.16 based networks and the cross layering framework can also be included to improve the QoS optimization.

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