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Performance Analysis of Wireless Ad-Hoc Network Based on EDCA IEEE802.11e

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Abstract**—**IEEE 802.11e is the enhanced version of the IEEE 802.11 MAC dedicated to provide Quality of Service of wireless network. It supports QoS by the service differentiation and prioritization mechanism. Data traffic receives different priority based on QoS requirements. Fundamentally, applications are divided into four Access Categories (AC). Each AC has its own buffer queue and behaves as an independent backoff entity. Every frame with a specific priority of data traffic is assigned to one of these access categories. IEEE 802.11e EDCA (Enhanced Distributed Channel Access) is designed to enhance the IEEE 802.11 DCF (Distributed Coordination Function) mechanisms by providing a distributed access method that can support service differentiation among different classes of traffic. Performance of IEEE 802.11e MAC layer with different ACs is evaluated to understand the actual benefits deriving from the MAC enhancements.

Keywords**—**802.11e, fairness, enhanced distributed channel access, access categories, quality of Service.

I. Introduction

POPULAR IEEE802.11 standard for wireless local area networks supports heterogeneous user applications at home and office. To support voice and video streaming, an enhanced version (IEEE802.11e) was proposed. Providing Quality of data traffic over a packet network is a challenge for IEEE 802.11 protocol. IEEE 802.11e enables service differentiation and support heterogeneous QoS requirements. It uses EDCA (Enhanced Distributed Channel Access) for service differentiation and providing QoS [10].

The paper is organized as follows: we first give an overview of the access mechanism of EDCA as well as transmission procedures. We present collision problems among ACs and analyze the resulting impact using NS-2.34 simulator. Finally, we evaluate the performance of EDCA IEEE802.11e through modification of EDCA parameters and compare to legacy IEEE 802.11. External collision is not considered in this work.

II. Basic Concept of IEEE802.11e EDCA

The EDCA scheme uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) and slotted Binary Exponential Back-off (BEB) mechanism as the basic access method. 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 EDCAF. Standard differentiation of AC's are best effort (AC_3), background (AC_2), video (AC_1) and voice (AC_0). AC with highest priority has the shorter CW so that the highest priority traffic can be transmitted earlier. The CW is determined from the range of CW_{min} [AC] and CW_{max} [AC] which is computed for different values of ACs. Different Interframe spaces (IFS) are used 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]. 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][12].

A. EDCA Transmission Procedure

An EDCAF (Enhanced Distributed Channel Access Function) contends for medium based on the following parameters associated to an AC: AIFS - The time period the medium is sensed idle before the transmission or backoff is started. CW_{min}, CW_{max} - Size of Contention Window used for backoff. Each station represents individual AC queues. Each queue has own different CW_{min}, CW_{max}, and AIFS. Fig. 1 shows the timing operations in 802.11e EDCA. To achieve differentiation, instead of using fixed DIFS (Distributed Interframe Space), EDCA assigns higher priority ACs with smaller CW_{min}, CW_{max}, and AIFS to influence the successful transmission probability (statistically) in favor of high-priority ACs [3]. 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, CW_{min} and CW_{max}) 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. Moreover, higher priority ACs has small contention windows, which is the reason they suffer from higher collisions. Two types of collision can be experienced [10]. 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

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leads to a situation referred to as internal collision or virtual 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.

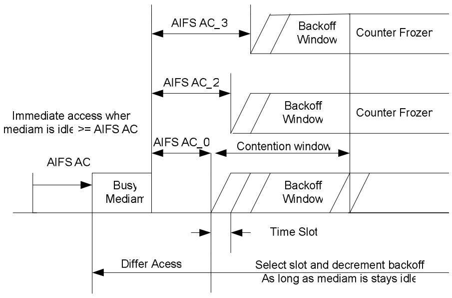

Fig. 1 EDCA AC transmit queues

III. Simulation Topology

Performance evaluation of IEEE 802.11e was conducted through simulations using the widely adopted Network Simulator NS-2.34, integrated with IEEE802.11e patch [15] and MPEG4 patch [14].

A. Common podium

The common topology consist ADHOC wireless network with number of stations as illustrated in Fig 2. Stations traffic flows is randomly generated and transmitted over the entire simulation environment.

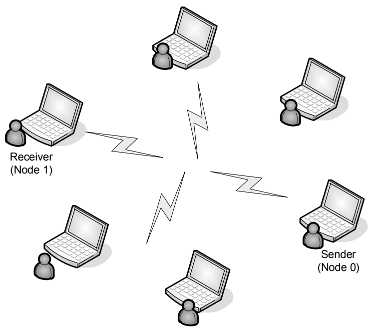

Fig. 2 Wireless simulation scenario

The AODV (Adhoc On Demand Vector) protocol in NS2.34 uses dynamic routing in order to deliver packets to any destination in an ad-hoc mode. However, transmission power is set in such a way that stations are within each other's transmission range. The following assumptions are made: static stations placement, RTS/CTS disabled, fragmentation of frame is disabled, two-ray propagation path loss model is implemented, traffic/application types are configured for AC_VO is RealAudio (built-in in NS-2.34 package [12]), for AC_VI is MPEG4, for AC_BE is CBR, for AC_BK is FTP. UDP is implemented as the Transport layer protocol for all except AC_BK. The size of each AC transmit queue is 50 frames. The CFB functionality is disabled, i.e., only one data frame is allowed to be transmitted after the medium is available.

B. Simulation Parameters for Scenario 1

Each AC has its own queue and behaves as an independent backoff entity. The priority among ACs is then determined by AC-specific parameters and used the preferred values of each mechanism parameters (see Table I and Table II).

For RealAudio traffic, packet size 160 byte, idle time 1800ms and burst time 0.05ms is used and for MPEG4, video traffic is transmitted as rate factor 1 with initial seed 0.5 where rate factor is, how much we need to scale up or down of video. Moreover, initial seed is start generating the first frame during simulation. IEEE802.11e basic transmission data rate is 1Mbps considered as default bandwidth of wireless link.

TABLE I
IEEE802.11E STANDARD EDCA PARAMETERS

Priority	Traffic	AIFS	CWmin	CWmax	TXOPlimit
0	Voice	2	7	15	0.003008
1	Video	2	15	31	0.006016
2	Best Effort	3	31	1023	0
3	Background	7	31	1023	0

EDCA standard parameters are selected for simulation scenario 1.

TABLE II
SIMULATION PARAMETERS FOR NS-2.34

Priority	Traffic[a]	Packet size(byte)	Data Rate
0	RealAudio	160	2Kbps
1	MPEG4	21-1020	30 frame/sec
2	CBR	200	125Kbps
3	TCP	40-1040	Default

EDCA simulation parameters are selected for simulation scenario 1. Traffics are used Real Audio, MPEG4[a] , CBR[a] , TCP[a] according to priority lebel.

[a]Different traffics ; MPEG4 = Moving Picture Experts Group 4, CBR = constant bit rate, TCP = Transmission Control Protocol.

C. Simulation Parameters for Scenario 2

In the scenario 2, the MAC parameters of IEEE 802.11e are changed considering higher prioritization of higher priority access category such as voice and less prioritized of data oriented access category such as TCP. The backoff-priority parameters have been set for each PriQ which is given below whereas other parameters remain unchanged (see Table III).

TABLE III
MODIFIED IEEE802.11E EDCA PARAMETERS

Priority	Traffic	AIFS	CW_{min}	CW_{max}	$TXOP_{limit}$
0	RealAudio	2	7	7	0
1	MPEG4	4	10	31	0
2	CBR	7	15	255	0
3	TCP	7	31	1023	0

IV. Simulation Result For Scenario 1

According to scenario 1, Simulation result of IEEE802.11e using standard parameters has been presented (see Table IV).

Note that, due to the nature of the model we used, active queues in this are necessarily saturated. Different traffic is transmitted from wireless node 0 to node 1 whereas CN (current node) is 1 and PT is packet type such as Audio, Video, CBR, and TCP. However, during simulation; throughputs (kbps) at node 1 and dropping packets statistics at node 0 has been analyzed (see Table V).

TABLE IV
Throughput Statistics Of Ieee802.11e Standard

Values	RealAudio (Kbps)	Video (Kbps)	CBR (Kbps)	TCP (Kbps)
Minimum	1.44	8.16	0.0	0.00
Average:	383.84	214.10	49.25	37.86
Max	486.72	258.68	88.00	108.16
Std. dev.	36.99	28.06	16.31	29.97

TABLE V
Dropping Packets Statistics At Node 0

Values	RealAudio (Kbps)	Video (Kbps)	CBR (Kbps)	TCP (Kbps)
No. of Packets	2269439	3	5759	12
No. of bytes	408499020	2140	1266980	11480

EDCA standard parameters are selected for simulation scenario 1. The dropping packets statistics at node 0 is in table V. Packet captured only for 120 Sec of the full Simulation time.

V. Simulation Result For Scenario 2

Using modified MAC parameters of IEEE802.11e, simulation result has been presented in fig. 4 by considering other parameters like transmission rate, fragmentation threshold as default. Also numerical statistics of different access categories are presented (Table VI and VII).

TABLE VI
Throughput Statistics Of Ieee802.11e Standard

Values	RealAudio (Kbps)	Video (Kbps)	CBR (Kbps)	TCP (Kbps)
Minimum	1.44	8.16	0.0	0.00
Average:	427.75	212.11	20.34	17.83
Max	506.88	269.70	47.52	99.84
Std. dev.	34.174	28.54	9.68	22.64

The throughput statistics of ieee802.11e standard is presented.

TABLE VII
Dropping Packets Statistics At Node 0

Values	RealAudio (Kbps)	Video (Kbps)	CBR (Kbps)	TCP (Kbps)
No. of Packets	2265687	3	7691	3
No. of bytes	407823660	2140	1692020	2120

The dropping packets statistics at node 0 is presented. Packet captured only 120 Sec of the full Simulation time.

VI. Simulation Analysis

EDCA's internal collision management represents potential priority inversion problem and fairness problem. Transmission of a packet the usual approach: $CW[AC_i] = CW_{min}[AC_i]$, where, i is the service differentiations. When collision occurs, the new contention window value becomes $CW_{new}[AC_i] = \min(2 \times CW[AC_i] + 1; CW_{max}[AC_i])$ in order to try to avoid further collisions [12]. The value of the contention window will grow exponentially until reaching $CW_{max}[AC_i]$. For this reason, when high priority traffic introduces internal collisions, the value of contention window could become longer than for low priority ACs. In the second problem, all queues of the same priority must have equal channel access probability.

A. Scenario 1

The first scenario shows us how EDCA behaves in IEEE802.11e; the throughput of the RealAudio (see table IV) is much higher than low priority access category (BE and BK). Hence, from the above results as in fig. 3, we conclude that the EDCA is able to provide service differentiation between different types of traffic flows. The higher priority traffic streams are better served than lower priority traffic streams. Also analyzed that in case of RealAudio (built-in package), number of packets are dropped leads to decrease of real-time performance and increase its delay compare to lower priority streams (see Table V).

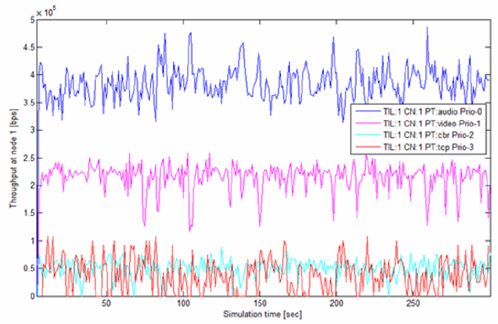

Fig. 3 Throughput at node 1 (Scenario 1)

B. Scenario 2

Compared to scenario 1, this approach will also allow higher total throughput for high priority traffic such as RealAudio (see Table VI) with reduced its contention window as shown in fig. 4. We can analyze that effects of varying the AIFS and CW, collision probabilities among ACs becomes affected. The throughput of BE (CBR) decreases while packet drops increase, as caused by internal collision probability. This is due to the increase in the collision probability, by reducing the size of its contention window (min and max) and increasing AIFS. So, this modified scheme gives us much more variation of throughout on access categories as in table VI.

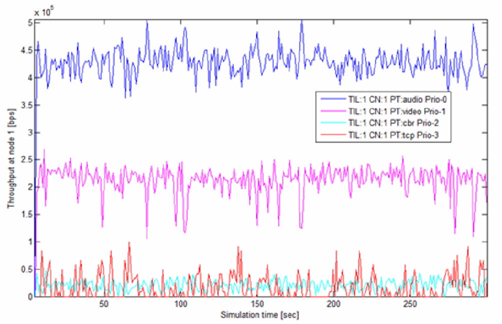

Fig. 4 Throughput at node 1 (Scenario 2)

As it is observed in table V and table VI, the number of packet drops is very high for RealAudio traffic. Because of their small Contention Windows, most of the collisions occur while transmitting AC_VO or AC_VI packets. Note that, a packet is dropped after the number of retransmissions reaches to the retry limit. The higher packet drops for AC_VO and AC_VI are due to the fact of collision rate (or rate of unsuccessful transmissions), which gives us a limitation of EDCA real time performance.

VII. Conclusion

In this paper, we have evaluated the performance of EDCA mechanism for QoS support in IEEE 802.11e WLAN looked into the different aspects of EDCA collisions. Through our simulations, we compared between different values of 802.11e legacies to show that EDCA provides differentiated channel access for different traffic types and is better equipped to handle real time applications with stringent QoS requirements. We find that small contention window values generate higher packet drops and collision rate probability. As a consequence, the EDCA mechanism suffers significantly. Better results can be obtained if we can adapt the EDCA parameters using fine tuned contention window mechanism, as proposed in the last section of the paper.

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