Performance Evaluation of the IEEE 802.11e EDCA Access Method

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Abstract

Wireless local area networks (WLANs) are increasingly popular because of their flexibility. This spreading of WLANs comes with an increasing use of multimedia applications. Such applications are bandwidth sensitive and require a quality of service (QoS) that guarantees high performance transmission of continuous data. This requirement is the focus of the new enhanced IEEE 802.11e standard protocol for WLANs. This paper presents a simulation study of the enhanced distributed channel access method (EDCA) in the new IEEE 802.11e standard protocol. This protocol is evaluated to verify that it achieves superior QoS performance for real-time applications compared with the earlier legacy IEEE 802.11 DCF access method. A Simulation experiments - using the network simulator NS2- are carried out to compare the performance of both protocols regarding the throughput, delay, and jitter.

Keywords: Infrastructure networks, Performance evaluation, IEEE 802.11e, EDCA, Simulation.

1. Introduction

Real-time applications are widely used nowadays in wireless networks. These applications exchange continuous data in the form of voice and video, and require special performance measures such as high bandwidth, low delay and jitter, which are collectively called quality of service (QoS).

IEEE 802.11 is the popular standard for WLANs. It works in the first two layers of the OSI reference model, the medium access control (MAC) and the physical (PHY) layer. It provides two MAC methods: Distributed Coordination Function (DCF) and Point Coordination Function (PCF). IEEE 802.11 did not achieve the required QoS performance for multimedia applications because it serves all transmitted frames with the same level of priority.

From this point, the IEEE Committee has developed a new standard called IEEE 802.11e to enhance the original 802.11 standard and support the required QoS. The IEEE 802.11e introduced a new access method called Hybrid Coordination Function (HCF) that enhanced the two original access methods and provided two enhanced mechanisms: Enhanced Distributed Channel Access (EDCA) and HCF Controlled Channel Access (HCCA). The main idea in both mechanisms depends on providing traffic classification to achieve priorities for real-time applications.

In this paper we study and evaluate the performance of the enhanced EDCA access method, and compare it with the legacy DCF access method. Four simulation experiments are conducted to validate the QoS performance offered to real-time traffic, and to answer the following questions:

- When best-effort and background traffic dominate a WLAN, would multimedia applications still get high QoS performance?
- When real-time traffic dominates a WLAN, would the low priority traffic suffer from starvation?
- How does EDCA provide different priority levels to different traffic categories? What is the mechanism that achieve that goal?

The remaining paper is organized as follows. Section 2 presents a brief description of the IEEE 802.11 DCF and the IEEE 802.11e EDCA access methods. Section 3 presents the simulation methodology, scenarios and parameters. In Section 4, simulation results are presented and discussed. The conclusion is given in Section 5.

2. Access Methods

The distributed coordination function (DCF) is the basic access method of the IEEE 802.11 protocol. It is based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) mechanism. The DCF uses for this purpose three main concepts: Interframe Space (IFS), Random Backoff, and Contention Window (CW). Details of the method are available in [1].

The enhanced distributed channel access (EDCA) is the access method of the IEEE 802.11e protocol [2]. Just like DCF, EDCA depends on contention windows to generate a random waiting time for each station before accessing the channel. EDCA provides differentiated service by providing distinct waiting times for four traffic priority levels. The standard defines four traffic types: Voice (VO), Video (VI), Best Effort (BE) and Background (BK). Voice is assigned the highest priority, whereas the background traffic is given the lowest. These priority levels are called Access Categories (AC). Table 1 shows a summary of these parameters, and their default values.

Table 1. Default EDCA parameters.

Priority Level	AC	CWmin	CWmax	AIFSN
0	VO	7	15	2
1	VI	15	31	2
2	BE	31	1023	3
3	BK	31	1023	7

2.1 The Contention Window

The parameters CWmin and CWmax determine the upper and lower values of the contention window for each access category (AC). The adjustment of the two variables, determines the range of the random backoff values, and hence the random waiting time before accessing the medium. Distinct CW ranges are assigned for different AC of the traffic classification. Based to the IEEE 802.11e draft [2], the idea behind the CW range is to give the high priority traffic small CW values and therefore, small waiting period before accessing the medium. On the other hand, a station having low priority traffic will have a large CW value and hence a large backoff counter and a long waiting time. In this way lower priority traffic gives the opportunity to higher priority traffic to capture the transmission medium first, and start transmission.

2.2 The Arbitration Interframe Space (AIFS)

This new IFS parameter replaces the distributed interframe space (DIFS) interval in the DCF access method. The AIFS value for a given access category should be set according to the following equation:

$AIFS = AIFSN \times SlotTime + SIFS$ Where,

- SlotTime is a time unit dictated by the underlying physical layer characteristics.
- SIFS is the short interframe space time period which is used for management and control frames.
- AIFSN is the Arbitration Interframe Space Number which determines the length of the AIFS.

3. Simulation Setup

The Network Simulator (NS2) [3] is used to conduct all simulation experiments. The original NS2 software supports the IEEE 802.11 only, and it was necessary to augment it with the new 802.11e. The EDCA setup is added using the TKN implementation of 802.11e [4].

3.1 Network Topology

We consider a wired/wireless topology having an infrastructure WLAN with a varying number of wireless stations, and one access point (AP) wired to a sink station, as shown in figure 1. All stations communicate with each other through the AP. All stations are located in the same domain with the AP. There is no mobility in the system to avoid the wireless problems such as the hidden node problem. All stations send CBR (constant bit rate) traffic to the wired station in a fixed sending rate and interval. UDP is implemented as the transport layer protocol.

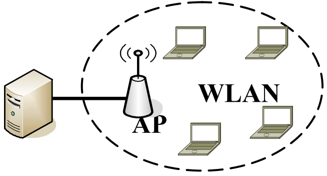


Figure 1. Network topology.

Different loads are considered by varying the number of wireless stations from 4 to 20. In addition to the default EDCA parameters in table 1, parameter settings for the simulated network are shown in table 2.

Table 2. Simulation parameters.

Parameter	Value	Parameter	Value
Interval	0.001 Sec	**SIFS time**	10 µs
Sending rate	1 Mbps	**DIFS time**	50 µs
data rate	54 Mbps	**CWmin (DCF)**	31
Slot time	20 µs	**CWmax (DCF)**	1023

3.2 Simulation Scenarios

EDCA is chosen here to study real-time traffic performance because it is valid for both ad-hoc and infrastructure scenarios. Two scenarios are considered. In both scenarios, each station generates the four types of data traffic mentioned in Section 2.

- **Scenario 1:** Using the same packet size of 256 bytes is used for all four ACs to emphasize the behavior of the enhancement,
- **Scenario 2:** A more realistic situation with different packet sizes for each AC. Voice, video, best-effort and background traffic are assigned packet sizes equal to 256, 512, 500 and 1000 bytes, respectively.

3.3 The Evaluation Process

Four simulation experiments are carried out to evaluate the performance. Each experiment is conducted using the scenarios mentioned in Section 3.2.

1. The first experiment is intended to prove the performance of EDCA compared with DCF. The expectations of the performance measures are obtained with 95% confidence intervals.
2. In the second experiment, the two access methods were studied at different levels of network load.
3. The third experiment verifies the robustness and fairness of the EDCA using different ratio of high and low priority stations.
4. The fourth experiment study the effect of the EDCA parameters (AIFSN, CW) on the results.

The results of all experiments are obtained using the AWK scripting language. The throughput AWK file is taken from [5], while the delay and jitter AWK files are developed in this study. All results are shown and explained in details in the next section.

4. Experiments and Results

In all simulation experiments the throughput, delay and jitter are used to evaluate and compare the performance of the two access methods DCF and EDCA.

4.1 Comparison Study

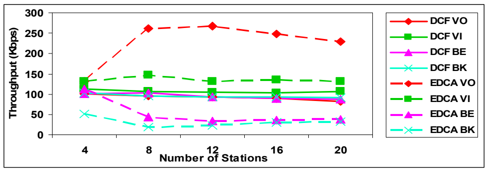
A fairly high network load is simulated by using one topology with 16 wireless stations and a fixed packet size for all access categories. A lengthy simulation run was conducted for 50 epochs to get precise results with a 95% confidence interval. Results in tables 3 prove that the EDCA method attains best performance for real-time traffic while DCF method deals with all traffic at the same priority level.

Table3. DCF and EDCA performance measures.

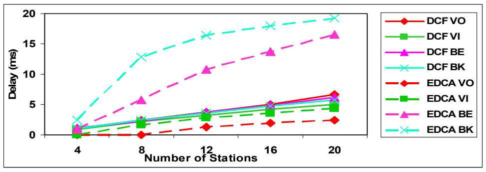
	AC	Throughput (Kbps)	Delay (ms)	Jitter (ms)
DCF	Voice	92.78 ± 4.18	4.8 ± 0.17	0.58 ± 0.17
	Video	91.99 ± 2.17	4.8 ± 0.1	0.57 ± 0.09
	BE	92.09 ± 1.62	4.79 ± 0.08	0.54 ± 0.06
	BK	93.81 ± 1.63	4.70 ± 0.07	0.5 ± 0.06
EDCA	Voice	256.17 ± 6.6	1.86 ± 0.08	0.2 ± 0.15
	Video	112.38 ± 1.7	4.03 ± 0.05	0.245 ± 0.04
	BE	8.9 ± 0.45	9.91 ± 0.23	2.77 ± 0.55
	BK	0.3 ± 0.04	8.13 ± 1.33	3.82 ± 0.9

4.2 Comprehensive Simulation Study

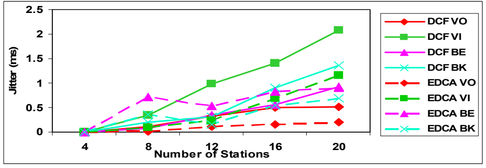
This experiment compares the performance of both access methods by varying the number of stations from 4 to 20. The simulation is carried out using the two scenarios, and the offered load for all access categories was equally set to obtain unbiased results. The results are shown in Fig. 2 and Fig. 3.



(a) Throughput

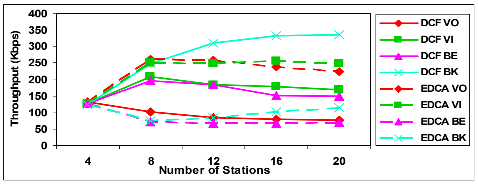


(b) Delay

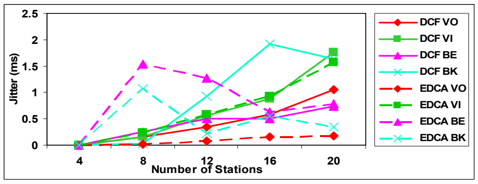


(c) Jitter

Figure 2. Network performance for scenario 1; fixed packet sizes.



(a) Throughput



(b) Jitter

Figure 3. Network performance for scenario 2; unequal packet sizes.

The above two results show similar performance regardless of the variations in the packet sizes. This indicates that these variations do not alter the high QoS performance which for real-time traffic in EDCA.

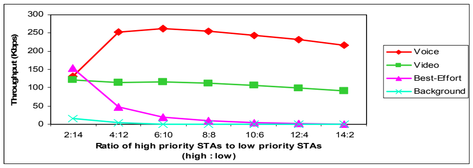
4.2.1 Throughput. Fig. 2a shows that all four streams in the DCF method have the same level of throughput. On the other hand, the EDCA offers high throughput for the multimedia traffic compared to normal data traffic. As the network becomes overloaded the EDCA mechanism starts to drop packets belonging to the low priority traffic (best-effort and background), while it continues to transmit the high priority traffic (voice and video) at a constant rate. The catch of this that EDCA behavior lies in the properly adjusted values of the AIFS and CW which are smaller for the high priority ACs than The low priority ACs. The high priority traffic is allowed to access the medium and start transmitting, while the low priority traffic remains counting down their counters. Also, fig. 3a proof the same results for EDCA while it affected with the varity in packet size in DCF access method.

4.2.2 Delay. Fig. 2b shows that DCF gives an equal opportunity to access the medium for all ACs. As the network gets overloaded, the delay keeps increasing for all ACs. This affects the voice and video traffic because the medium can not guarantee an acceptable performance for multimedia applications. This results in large time gaps between packets and therefore poor multimedia synchronization. EDCA guarantees a low delay for the high priority traffic and therefore small waiting time to access the medium. The same results were obtained for the case of unequal packet size.

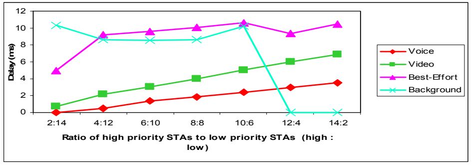
4.2.3 Jitter. Fig. 2c and fig. 3b show that in the DCF the delay variations are well observed in voice and video traffic. There are no specific rules to differentiate between the high and low priority ACs in accessing the medium. These causes unpredictable delay variation, and can not give guaranteed low jitter for the high priority traffic. On the other hand, the EDCA gives a stable scale of increasing delay of the four ACs with low jitter for voice and video until using 8 wireless stations. Beyond this level of load, the voice traffic has stable low jitter and the video traffic jitter starts to increase until the highest network load. Varying levels of jitter are observed for the low priority traffic; however, this is irrelevant for non-real-time traffic.

4.3 Confirming High Priority Performance

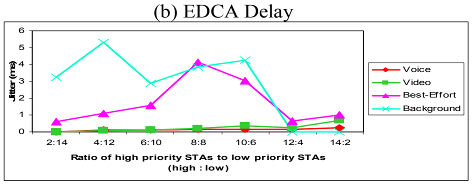
This experiment aims to study the effect of changing the traffic mix by altering the ratio between real-time and non-real-time traffic, using a topology of 16 stations. Seven cases are studied as shown in Fig. 4. The case (R:N) means R real-time stations and N non-real-time stations, given that R+N=16. The test is carried out using the EDCA and fixed packet sizes for all ACs. The obtained results prove that EDCA guarantees high QoS performance to real-time traffic in all cases. This is manifested in the high throughput, low delay and low jitter.



(a) EDCA Throughput



(b) EDCA Delay



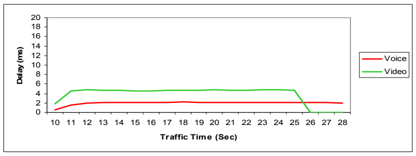
(c) EDCA Jitter

Figure 4. Network performance at different traffic mix.

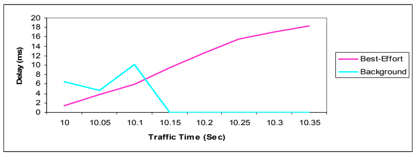
4.4 The EDCA Priority Mechanism

This experiment investigates the EDCA priority mechanism, using a 16 stations network and fixed size packets. Four cases are considered to study the effect of EDCA parameters (AIFSN and CW) in setting the access priorities. Case1 assigned the default values for AIFSN and CW as explained before in table 1. Case2 using equal AIFSN values for all ACs. Case3 using equal CW values for all ACs. Case4 using equal AIFSN and CW values for all ACs.

4.4.1 Default EDCA parameters (Case1). Fig. 5 shows that voice and video traffic have a stable level in delay results while best-effort and background traffic have unpredictable delay, simply because their parameter values correspond to low access priorities.



(a) EDCA Voice and Video Delay



(b) EDCA Best-Effort and Background Delay

Figure 5. Network performance using default EDCA parameters.

4.4.2 Equal AIFSN values (Case2). AIFSN is used in EDCA to calculate the value of the arbitration interframe space (AIFS), which controls the waiting time. AIFSN is set to the smallest value of 2 for all ACs, which is actually the default for voice and video. Consequently, the same results of Fig. 5a apply here as well. For best-effort traffic, the AIFSN is changed from 3 to 2, and therefore the obtained performance in Fig. 6 is more or less the same as that of Fig.5b in case 1. For the background traffic, AIFSN is changed from 7 to 2 which accounts for the improved performance. These results indicate that using the same value of the AIFSN parameter to all ACs does not have any affect on the priority mechanism of the EDCA for real-time traffic.

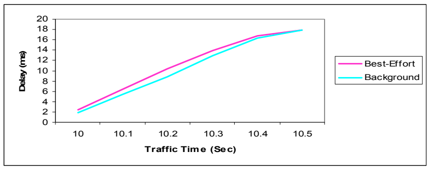


Figure 6. Network performance using equal AIFSN values.

4.4.3 Equal CW values (Case3). Here, the same CWmin and CWmax values of 31 and 1023, respectively, are assigned to all ACs. These two parameters control the length of the random part of the waiting time. Fig.7 shows the delay for all ACs, except the background traffic has more or less the same stable and low values as shown in Fig. 6. Background traffic does not have the same performance because it still has a large AIFSN value of 7. This result shows that the AIFSN parameter has a strong effect on the delay.

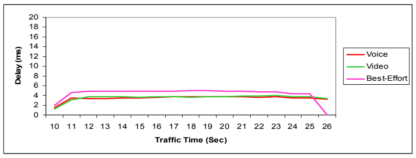


Figure 7. Network performance using equal CW values.

4.4.4 Equal values for CW and AIFSN (Case4). Fig.8 shows the delay results for all four ACs, which are more or less the same. This test shows that the EDCA access method behaves exactly as the DCF when its parameters are equally set for all ACs.

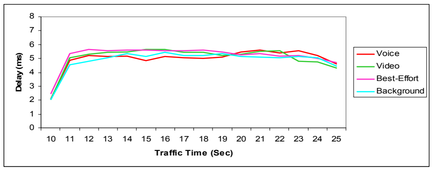


Figure 8. Network performance using equal values for CW and AIFSN.

5. Conclusion

Simulation is used to investigate the performance of the new WLAN standard IEEE 802.11e and compare it with the legacy protocol. Simulation experiments are carried out using an infrastructure wireless network under different network loads and different mixtures of traffic. The traffic mix is changed by varying the ratio of real-time packets to non-real-time packets using fixed and different packet sizes, to be more realistic.

The QoS performance is evaluated to measure throughput, delay, and jitter. Several simulations are conducted, and all results have confirmed, with quantitative evidence, as follows:

- The EDCA access method of provides superior QoS performance for real-time traffic as compared to other common traffic. This is manifested in a higher throughput, lower delay and lower jitter in favor of the real-time traffic.
- Real-time traffic will get superior QoS performance even if the best-effort and background traffic dominate the network traffic.
- Non-real-time traffic will have an opportunity to pass over the wireless network and will not suffer from starvation even if the voice and video traffic dominate the network traffic.

The obtained results revealed that the priority levels in the IEEE 802.11e protocol are based on the combination of the two protocol parameters (CW) and (AIFSN). The default settings specified in the IEEE 802.11e draft enforce the correct priority level for each AC. Setting both parameters equally for all four ACs, causes the IEEE 802.11e protocol to perform identically as the legacy IEEE 802.11 protocol.

6. References

[1] IEEE Std. 802.11-1999, “Part11:Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications”, Reference number ISO/IEC 8802-11:1999(E), IEEE Std 802.11, 1999 edition IEEE (1999). Revised in (2003).

[2] IEEE 802.11e, “Supplement to Part 11: Wireless Medium Access Control (MAC) and physical layer (PHY) specifications: Medium Access Control (MAC) Enhancements for Quality of Service (QoS)”, IEEE Std. 802.11e-2005 IEEE (2005).

[3] http://www.isi.edu, accessed on August 2006.

[4] S. Wiethölter and C. Hoene, “Design and Verification of An IEEE 802.11e EDCF Simulation Model in ns-2.26”, Tech. Rep. TKN-03-019, Technische Universität Berlin (2003).

[5] http://140.116.72.80/~smallko/ns2/tool_en.htm, accessed on January 2008.