# QoS Analysis of IEEE 802.11e EDCF

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*Abstract* - **The scope of this paper is performance analysis of DCF and EDCF in 802.11 wireless LANs. The analyses are performed for EDCF with and without CFB, for different traffic types, such as voice, video and data. Using simulation methodology we have found that QoS parameters, such as throughput, packet delay and jitter, significantly depend upon the choice of the 802.11e parameters such as AIFS, CW, and TXOP.**

*Keywords*: **IEEE 802.11e, Quality of Service, Traffic**

## I. INTRODUCTION

IEEE 802.11e Medium Access Control (MAC) is an emerging supplement to the IEEE 802.11 Wireless Local Area Network (WLAN) standard to support Quality-of-Service (QoS). The 802.11e MAC is based on both centrally-controlled and contention-based channel access. In this paper we evaluate the contention-based channel access mechanism, called enhanced distributed coordination function (EDCF), in comparison with the 802.11 legacy distributed coordination function (DCF) [1-4]. The EDCF provides differentiated channel access to frames with different priorities. We also consider an optional feature of the EDCF, called contention-free burst (CFB), which allows multiple MAC frame transmissions during a single transmission opportunity (TXOP). Furthermore, the CFB is found to enhance the EDCF performance by increasing the overall throughput and significantly decreasing delay, especially in case of transmission of video applications.

In this paper we compare the performance of the existing 802.11 MAC and the proposed 802.11e draft standard by simulating the protocols in Network Simulator v2.26 [5].

The paper is organized as follows. In the next two sections we describe briefly DCF and Enhanced DCF. Further, Section 4 gives details on CFB. Simulation analyses are presented in Section 5. Finally, Section 6 concludes the paper.

## II. 802.11 DCF

The 802.11 standard specifies two channel access functions: the mandatory distributed coordination function (DCF) and optional point coordination function (PCF). Most of today's 802.11 devices operate in the DCF mode only. In this section we explain how the DCF works, because it is the basis for the Enhanced DCF (EDCF), which is the scope of our work in this paper. The diagram of DCF channel access is illustrated in Fig.1.

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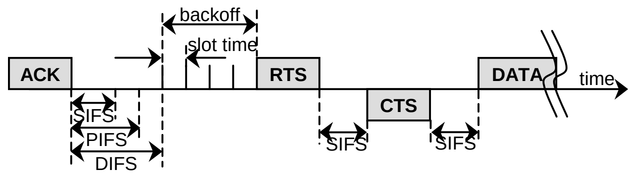



Fig.1 IEEE 802.11 DCF Channel Access

TABLE 1
MAC PARAMETERS FOR 802.11b PHY

| Parameters | 802.11b PHY |
|---|---|
| SIFS (μsec) | 10 |
| DIFS (μsec) | 50 |
| Slot Time (μsec) | 20 |
| CWmin | 31 |
| CWmax | 1023 |

All of the MAC parameters including SIFS, DIFS, Slot Time, CWmin, and CWmax are dependent on the underlying physical layer (PHY). Table 1 shows these values for the 802.11b PHY. Irrespective of the PHY, DIFS is determined by SIFS+2·SlotTime, and another important IFS, called PCF interframe space (PIFS), is determined by SIFS+SlotTime. With 802.11b, the transmission rate is up to 11 Mbps.

## III. 802.11E MAC ENHANCED DCF (EDCF)

EDCF enhances the original DCF to provide prioritized QoS, i.e. QoS based on priority of access to the wireless medium. Prioritized QoS is realized through the introduction of four access categories (AC), as given in Table 2. Each AC has its own transmit queue and its own set of AC parameters.

TABLE 2
PRIORITY TO ACCESS CATEGORY MAPPINGS

| Priority | Access Category | Designation |
|---|---|---|
| 1 | 0 | Best Effort |
| 2 | 0 | Best Effort |
| 0 | 0 | Best Effort |
| 3 | 1 | Video Probe |
| 4 | 2 | Video |
| 5 | 2 | Video |
| 6 | 3 | Voice |
| 7 | 3 | Voice |

As distinct from the legacy DCF, the EDCF is not a separate coordination function. Rather, it is a part of a single coordination function, called the Hybrid Coordination Function (HCF), of the 802.11e MAC [4]. The HCF combines the aspects of both DCF and PCF. All the detailed aspects of the HCF are beyond the scope of this paper as we focus on the

HCF contention-based channel access, i.e., EDCF. Fig.2 shows the timing diagram of the EDCF channel access.

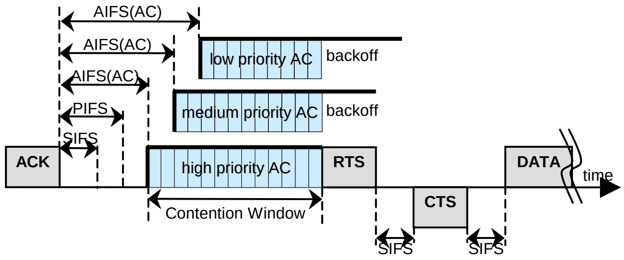



Fig.2 IEEE 802.11e EDCF channel access

The IEEE 802.11e defines a transmission opportunity (TXOP) as the interval of time when a particular station has the right to initiate transmissions. Along with the EDCF parameters of AIFS[AC], CWmin[AC], and CWmax[AP], the AP also determines and announces the limit of an EDCF TXOP interval for each AC, i.e., TXOPLimit[AC], in beacon frames. The AP can adapt these parameters dynamically depending on network conditions.

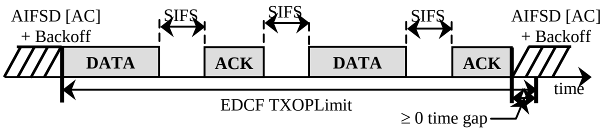



Fig.3. CFB timing structure

A single station may implement up to four transmission queues realized as virtual stations inside a station, with QoS parameters that determine their priorities. If the counters of two or more parallel ACs in a single station reach zero at the same time, a scheduler inside the station avoids the virtual collision. That is, the highest priority frame among the colliding frames is chosen and transmitted, and the others perform a backoff with increased CW values. There is then still a possibility that the transmitted frame collides at the wireless medium with a frame transmitted by other station.

## IV. Contention Free Burst (CFB)

During an EDCF TXOP, a STA is allowed to transmit multiple MSDUs from the same AC with a SIFS time gap between an ACK and the subsequent frame transmission. We refer this multiple MSDU transmission to as Contention-Free Burst (CFB).

CFB was introduced to improve the performance for small packets (of timebounded services) in Wireless LANs by decreasing overhead and delay and by increasing the throughput. CFB basically uses the idea of a fragment burst (of 802.11 DCF) where a station sends small fragments of a large MSDU as a burst if it gains access to the medium. With CFB, not fragments of one large MSDU but a series of small MSDUs are transmitted in a burst. It is possible to send packets to different destinations in one burst frame. Between an ACK and the following packet only a time interval of SIFS is required. Therefore the station keeps control over the medium for the whole burst. Sending multiple small packets in a burst avoids contention for each single packet. This results in a higher efficiency and lower delay.

Fig.3 shows the transmission of two QoS data frames during an EDCF TXOP, where the whole transmission time for two data and ACK frames is less than the EDCF TXOP limit announced by the AP. As multiple MSDU transmission honors the TXOP limit, the worst-case delay performance is not affected by allowing the CFB. We show further that CFB increases the system throughput without degrading other system performance measures unacceptably as long as the EDCF TXOP limit value is properly determined.

## V. Simulations

Our simulations are done with Network Simulator version 2.26. The scenario is consisted of one access point (AP) connected with server via switch from one side and eight wireless stations (WS) around it; each station except AP generates only a single type of traffic, and hence, for example, we refer to a station that generates video traffic as a video station. There are three possible directions of traffic stream: from a station toward the server (uplink), from the server towards a station (downlink) and from a station to a station. Most of the stations transmit towards server and receive from server too, except two voice stations that communicate among them.

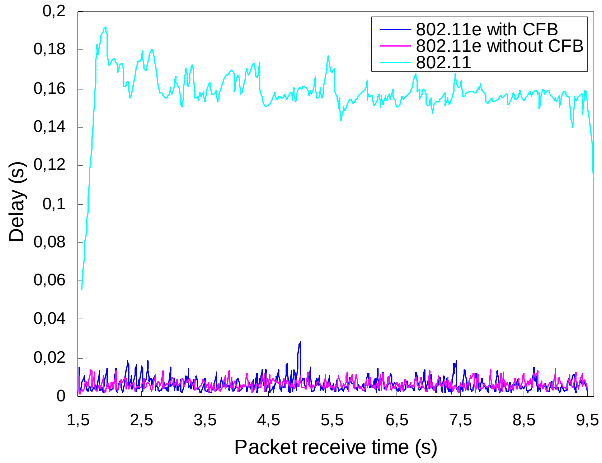
TABLE 3
Traffic Types and Characteristics

| Type | Agent/ Application | Frame Size (bytes) | Data Rate (Mbps) |
|---|---|---|---|
| Voice | UDP/CBR | 92 | 0.0368 |
| Video | UDP/CBR | 1464 | 1.4 |
| Data | TCP/FTP | 1500 | 1.0 |

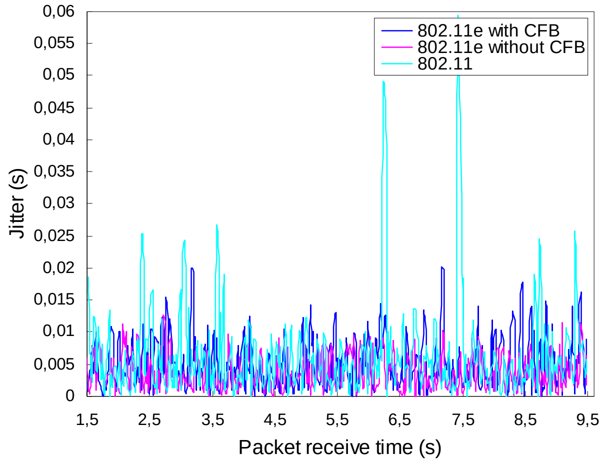
TABLE 4
EDCF Parameters 1

| Type | AC | AIFS | CWmin | CWmax | TXOP Limit |
|---|---|---|---|---|---|
| Voice | 3 | 1 | 7 | 15 | 0.003000 |
| Video | 2 | 1 | 15 | 31 | 0.006000 |
| Video Probe | 1 | 1 | 31 | 1023 | 0.003000 |
| Data | 0 | 2 | 31 | 1023 | 0 |

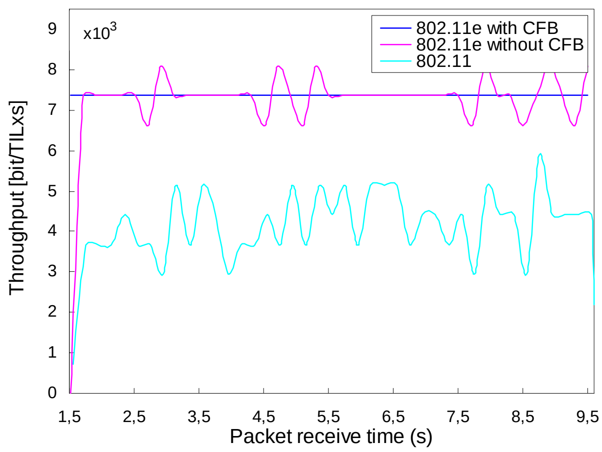
Two stations generate and receive the data traffic (with the lowest priority – AC0), two stations generate video probe signal (AC1) and receive the video traffic (AC2) and four stations generate and receive voice traffic (AC3). The AP transmit all kind of traffic (except video probe) generated from the server towards wireless nodes and receive all kind of traffic (except video) from wireless nodes towards server. Table 3 shows the traffic types and their characteristics that we used for our simulations. Basically, four different types of traffic are considered, namely, voice, video, video probe and data. Voice, video and video probe traffic is assumed to be of constant bit rate (CBR). Data traffic is assumed to be FTP traffic.




a) Delay for voice stations

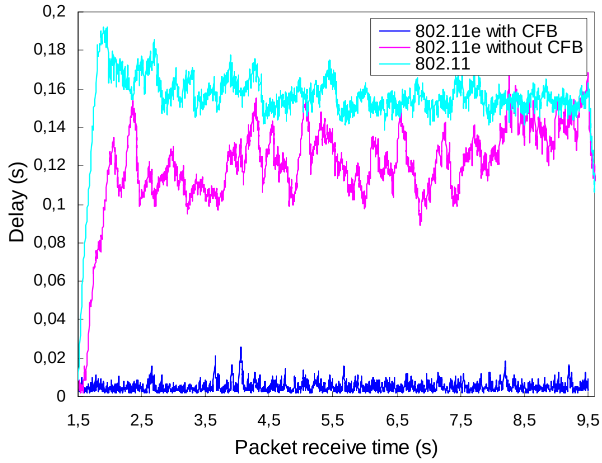



b) Jitter for voice stations

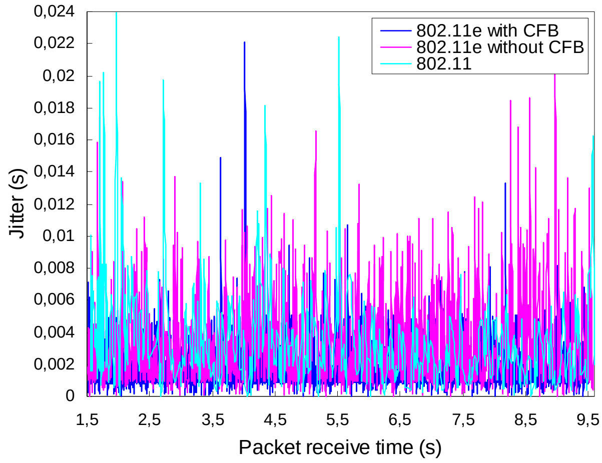



c) Throughput for voice stations

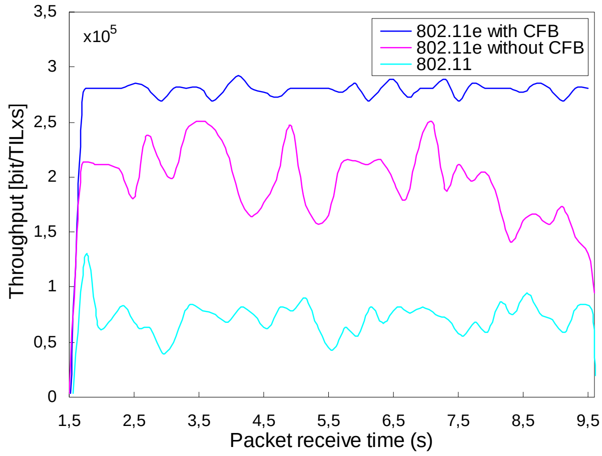
Fig.4. Comparison between 802.11, 802.11e with CFB and 802.11e without CFB for voice traffic




a) Delay for video stations




b) Jitter for video stations




c) Throughput for video stations

Fig.5. Comparison between 802.11, 802.11e with CFB and 802.11e without CFB for video traffic

In our simulations we follow the behavior of the stations in the case of either DCF or EDCF implemented, i.e. the 802.11 stations versus QoS 802.11e stations. We measure the throughput, delay and the jitter of receiving bits in destination stations and evaluate the benefit of including different priorities for different kinds of traffic. We do the same simulations twice: first time with CFB not implemented, and the second time with CFB implemented in order to show the utility of the CFB.

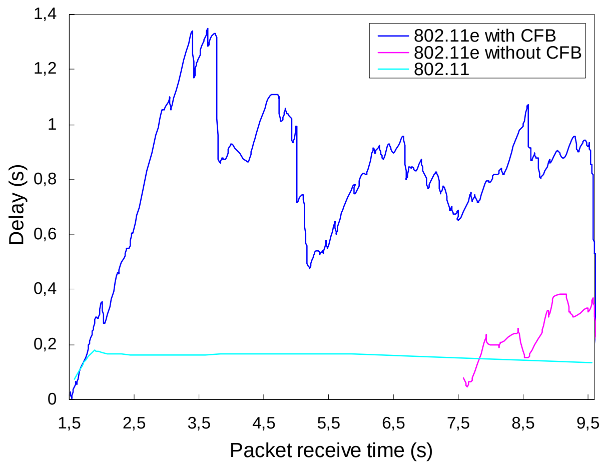
We observe in Fig.4 that voice performance is significantly improved via the EDCF. Note that with the DCF, the voice frame delay sometimes goes over 250 ms, which is not acceptable in most cases. From the Fig.4c we can see that the curve representing throughput for the voice station with EDCF is almost flat. Thereat, the throughput with CFB is slightly better than without CFB.

The video performance is also improved remarkably with the EDCF. We now also observe from Fig.5a that the video delay performance is significantly improved with CFB as the video stations enjoy reduced overheads for backoff. The throughput is much better and varying much less with time then in case of DCF or EDCF without CFB (Fig.5c).

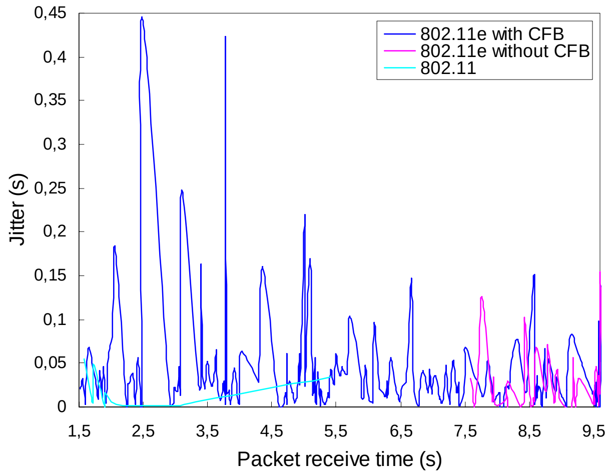
Regarding the data traffic, the results are very varying, as we expect it (Fig.6). Usually the throughput with the EDCF is better than one with the DCF, but the delay and jitter are worse, that is not surprising having in mind the 802.11e parameters for data traffic (Table 4). But delay and jitter are not critical for data traffic when compared to voice and video traffic, hence the EDCF does not make degradation of one kind of traffic in expense of the other.

# VI. Conclusion

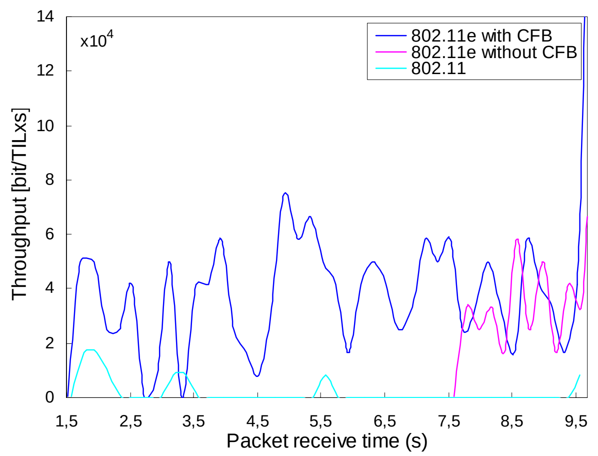
In this paper, we have analyzed the contention-based channel access scheme for QoS support, called the EDCF, of the IEEE 802.11e MAC. Based on the simulation, we compared the legacy 802.11 DCF and the 802.11e EDCF to show that the EDCF can provide differentiated channel access among different traffic types. We have also evaluated an optional feature called CFB, which allows a station to transmit multiple MSDUs with the SIFS time gaps within the time bound of the TXOP limit. The CFB is shown to improve the global system performance especially for the video traffic where the improvements are remarkable.




a) Delay for data stations




b) Jitter for data stations




c) Throughput for data stations

Fig.6. Comparison between 802.11, 802.11e with CFB and 802.11e without CFB for data traffic

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