Performance Evaluation of Real-Time Application for EDCA Function in IEEE 802.11e WLAN

Riyadh Qashi

Faculty of Mathematics and Computer Engineering, University of Leipzig, Johannisgasse 26, 04103 Leipzig, Germany

Received: October 11, 2011 / Accepted: October 19, 2011 / Published: May 31, 2012.

Abstract: The IEEE 802.11 standard is a widely used base for wireless local area network (WLAN) infrastructure, because of its easy deployment. But it cannot provide QoS support for an increasing number of multimedia applications. With deployment of WLAN, the ability of the IEEE802.11 standard to support multimedia applications with high quality of service (QoS) requirements has increased. This paper evaluates the capacity of QoS support in Enhanced Distributed Channel Access (EDCA) mechanism of the IEEE 802.11e standard. The EDCA is an enhancement for QoS support in 802.11. EDCA mechanisms allow prioritized medium access for applications with high QoS requirements by assigning different priorities to the access categories. This paper discusses the performance limitation of 802.11e and 802.11. The parameters delay and throughput are discussed in two different scenarios. A comparative discussion between DCF und EDCA is constituted for different services, such as voice, video, best-effort and background traffic. The simulation results show the QoS support of 802.11e standard for different types of data traffic due to its service differentiation technique. With EDCA mechanism, network capacity is effectively increased and the support for multimedia applications transmissions is improved.

Key words: IEEE 802.11e, UDP, (Enhanced Distributed Channel Access) EDCA, (quality of service) QoS, (Distributed Coordination Function) DCF, AC, WLAN.

1. Introduction

The IEEE 802.11 standard is a significant milestone in the provisioning of network connectivity for mobile users. However, due to the time-dependence characteristics of wireless links, interference from other devices and terminal mobility, 802.11-based wireless local area networks (WLAN’s) suffer from performance drawbacks in relation to wired networks. In order to provide a proper wireless networking service for real-time applications, securing the quality-of-service (QoS), lower information (packet) loss and minimum latency should be featured. In order to provide a sufficient QoS for real time applications, the transfer service should be carried out via different priorities.

The architecture of IEEE 802.11 standard includes the definitions of Medium Access Control (MAC) layer and Physical Layer (PHY). Its MAC layer already provides two basic access methods: DCF (Distributed Coordination Function) and PCF (Point Coordination Function): (1) DCF uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol, and it is best known for asynchronous data transmission. (2) PCF uses a central-controlled polling method to support synchronous data transmission [1]. Up to now, only DCF is implemented in application devices [3, 14]. The IEEE802.11 wireless networks can be configured into two different modes: ad hoc and infrastructure modes. In ad hoc mode, all wireless stations within the communication range can communicate directly with each other, whereas in infrastructure mode, an access point is needed to connect all stations to a Distribution System, and each station can communicate with others through the access point [12].
The IEEE 802.11 DCF can only provide best-effort services without any QoS guarantee [1]. In DCF, every station statistically has the same probability to access the channel and transmit no matter what kinds of traffic they are sending. Obviously, this kind of channel access mechanism is challenged by time bounded services, such as VoWLAN, video conferencing, requiring guaranteed bandwidth, delay and jitter [2]. Without prioritized traffic, a station may have to wait an arbitrarily long time before it gets the chance to transmit so that these real-time applications may suffer [15]. In order to support application with QoS requirements, the IEEE 802.11 standard group has specified the IEEE 802.11e standard. The EDCF (IEEE 802.11e) protocol supports QoS and provides different services.

In this study, the capacity of the transfer is investigated, using the enhanced distributed channel access (EDCA) along with different access categories (ACs: AC0, AC1, AC2 and AC3) [6]. The simulation is done using the INETMANET framework OmNET++ [4-5]. Moreover, a comparison between DCF and EDCA is made.

The paper is organized as follows. In Sections 2 and 3, the DCF and EDCA are described respectively. The simulation and corresponding analysis of the capacity of EDCA with different ACs are explained in Section 4. Finally concluding remarks are given in Section 5.

2. DCF

The DCF of IEEE 802.11 is a fundamental MAC method and is based on the CSMA/CA protocol [6]. The DCF uses the CSMA/CA protocol and it is implemented for asynchronous transmission (best-effort). The DCF works with a single first-in-first-out (FIFO) transmission queue. The CSMA/CA comprises a distributed MAC based on a local assessment of the channel status, i.e., whether the channel is busy or idle. The initiation of delivery for any packet is preceded by the detection of the station’s wireless medium. The medium should be idle for a minimum duration called DCF interframe space (DIFS). The station selects, randomly, the backoff timer interval from \([0, \text{CW}_{\text{min}}]\) (CW: contention window); the backoff time determined by

\[
\text{backofftime} = \text{backoff-counter} \times \text{SlotTime}
\]

(1)

Where the SlotTime parameter depends on the underlying PHY, and then enters the backoff process [7]. Parallel to the count-down of the backoff timer, if the station detects the busy state of the medium, it stops decrementing the timer and does not reactivate the paused value until the channel is sensed idle again for more than a DIFS period. When a timer expires, the station is free to access the medium for a new packet transmission. When an acknowledgment frame is received, the transmission is considered successfully. The acknowledgment frame is transmitted after a short IFS (SIFS), which is shorter than the DIFS. As the SIFS is shorter than DIFS, the transmission of acknowledgment frame is protected from other station’s contention. The CW is reset to minimum \(\text{CW}_{\text{min}}\) and the station stands-by for the next packet arrival. The transmission is considered failed if no acknowledgment is received within a specified timeout; the station repeats the backoff process with \(\text{CW}\) selection range doubled up to maximum contention window, \(\text{CW}_{\text{max}}\). If the transmission has been re-tried for up to \(\text{RetryLimit}\) times, the packet will be discarded and the CW is reset to \(\text{CW}_{\text{min}}\) [8-9]. Note, the MAC parameters including SIFS, DIFS, SlotTime, \(\text{CW}_{\text{min}}\), and \(\text{CW}_{\text{max}}\) are dependent on the underlying physical layer (PHY). The typical values of QoS-Parameter for different ACs are shown in Table 1.

<table>
<thead>
<tr>
<th>ACs</th>
<th>(\text{CW}_{\text{min}})</th>
<th>(\text{CW}_{\text{max}})</th>
<th>ALFSN</th>
<th>TXOP Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC0</td>
<td>31</td>
<td>1023</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>AC1</td>
<td>31</td>
<td>1023</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>AC2</td>
<td>15</td>
<td>31</td>
<td>1</td>
<td>3ms</td>
</tr>
<tr>
<td>AC3</td>
<td>7</td>
<td>15</td>
<td>1</td>
<td>105ms</td>
</tr>
</tbody>
</table>
3. EDCA

The EDCF is an enhancement of DCF and provides prioritized QoS support among different types of traffic [9, 15]. Each QoS-station defines eight user-priorities and maps the packets arriving at MAC layer into four different ACs (also known as EDCA), see Fig. 1. It assigns a set of backoff parameters, namely arbitration interframe space (AIFS), with the boundaries $CW_{\text{min}}$ and $CW_{\text{max}}$ to each AC. Each AC uses its own backoff parameters to compete for the wireless medium by the same backoff rules as DCF stations described before, see Fig. 2. The AIFS [AC], determined by

$$AIFS[AC] = AIFSN[AC] \times \text{SlotTime} + \text{SIFS}.$$  

(2)

It replaces the fixed DIFS in DCF (SIFS: short interframe space). The timing relationship of EDCA is shown in Fig. 2. Shorter AIFS[AC] in higher priority AC allow earlier timing for high priority traffic in order to unfreeze the paused timer after each busy wait period [3]. However, smaller CW sizes (statistically seen) provide shorter backoff stages to high priority traffic, see Ref. [8] for more details. An internal collision occurs when more than one AC finishes the backoff at the same time. In such a case, a virtual collision handler in every QoS-station allows only the highest-priority AC to transmit frames, and the others perform a backoff with increased CW values [10].

Transmission opportunity (TXOP) is defined in IEEE 802.11e as the interval of time when a particular QoS-Station has the right to initiate transmissions. The TXOP describes the sending interval, sending-start time and transfer period [13]. There are two modes of EDCA TXOP defined, the initiation of the EDCA TXOP and the multiple frame transmission within an EDCA TXOP [15]. An initiation of the TXOP occurs when the EDCA rules allow access to the medium. A multiple frame transmission within the TXOP occurs when an EDCAF retains the right to access the medium after the completion of a frame exchange sequence, e.g., on receipt of an acknowledgment frame. The TXOP limit duration values are announced by the QoS-Access Point in the EDCA Parameter Set Information Element in Beacon frames. During an EDCA TXOP, a station is permitted to transmit multiple MAC protocol data units (MPDUs) from the same AC with a SIFS time gap between an acknowledgment and the subsequent frame transmission. Hence, the throughput is raised. A TXOP limit value of 0 indicates that a single MPDU may be transmitted for each TXOP, see Refs. [7, 15] for more details.

4. Results and Discussion

4.1 Simulation Setup

This section used the Network Simulator Omnet++ and the available structures in the Inetmanet
framework [5] to evaluate the performance of IEEE 802.11e EDCA mechanism and to compare this performance with the performance in DCF [11]. Two simulations have been considered, namely scenario 1, scenario 2. Scenario 1, within simulation, the client station has an Ethernet-frames generator, while the access point features a sink which measures the throughput. The simulation is done once for DCF and once for each AC (total of 4). In scenario 2 have been used an AP, Server and a station. The server contains the type UDPVideoStreamSv. The station has four UDP (User Datagram Protocol) applications that use the type UDPVideoStreamCli. The types UDPVideoStreamSv (Streaming video server) and UDPVideoStreamCli (video streaming client) are used together to send and receive UDP packets. The simulation is done for each EDCF and DCF in both scenarios.

Consistent with specifications the four Access Category (ACs), background data under AC0 (lowest priority), best-effort traffic under AC1, video traffic under AC2 and voice traffic is carried under AC3 (highest priority). In scenario 2, the voice traffic started at second 5, video at second 10, best-effort and background at second 15. Both scenario used 1.5 ms interval between sending the streams packets. The DCF mechanism uses the Best-Effort principal.

In both scenarios, all PHY parameters are taken according to IEEE 802.11 standard: the maximum data rate is set to 11 Mbps and SlotTime = 20 ms. CW\_min and CW\_max are set to 31 and 1023 respectively while Short-IFS is set to 10 ms. The simulation parameters are shown in the Table 1 for EDCA.

### 4.2 Simulation Results for Scenario1

Fig. 3 shows the throughput for DCF and EDCF cases, which illustrates the effect of EDCA parameters on the realized throughput. It is shown that the throughput of AC3 is significantly higher than AC0 and AC1. This means that channel access opportunity is high because of AIFS = 1 and CW\_min = 7. The value of AIFS of AC3 is smaller than that of AC2, AC1 and AC0.

Fig. 3 shows that both, the traffic of AC0 and the traffic in DCF, have similar throughput values; because parameters of AC1 during simulation become close in value to those parameters from DCF. Thus, EDCA offers the highest throughput for both voice and video applications (voice over-IP and videoconferencing) by providing higher priority of transfer for these applications. The mean throughput from EDCF is 5.5 ± 0.5 Mbps while it is 5.07 ± 0.5 Mbps for DCF; note that the maximum theoretical achievable throughput using 802.11 is bounded by 6.4 Mbps [10]. As illustrated in Fig. 3, the traffic with high priority AC3 allocates more resources than other ACs. This means that the channel access opportunity is high because of AIFS = 1 and CW\_min = 7. The value of AIFS of AC3 is smaller than that of AC2, AC1 and AC0. Fig. 3 shows that both, the traffic of AC0 and the traffic in DCF, have similar throughput values; because the parameters of AC1 during simulation become close in value to those parameters from DCF.

Fig. 4 gives the corresponding latency in transfer for the different ACs with an over all mean value of 20.0 ± 0.1 ms for EDCF and 21.7 ± 0.3 ms (estimated) for DCF. The best performance (lowest delay) is achieved using AC2 and AC3. Both results emphasize the superior performance of EDCF over DCF in case
4.3 Simulation Results for Scenario 2

The comparison of the mean throughputs of each traffic type, which started in different times, is plotted in Figs. 5 and 6. The figures show the effect of service differentiation on four concurrent UDP streams in DCF and EDCA, each set with a different access category. The figures show, that the mean throughputs of voice, video, background and best-effort data are significantly different for the DCF and the EDCA.

In EDCA, the throughput of voice traffic (4.41 Mbps) is higher than the throughput of voice for DCF (1.19 Mbps). When the video traffic is started at 10 secs, it can be observed, that the throughput of voice traffic drops from around 5.19 Mbps to 4.41 Mbps, confirming that the voice traffic is well served with the EDCA. In DCF, the throughput of voice traffic drops from around 5.1 Mbps to 1.79 Mbps.

When background and best-effort traffic is started at 15 secs, in case of DCF, the video throughput drops down by about 30% (from about 2.6 Mbps down to about 1.8 Mbps), in case of EDCA, the video throughput stays nearly unchanged within statistical errors. It can also be seen that the throughput of background and best-effort is low in EDCA as compared to DCF. This happens because the DCF serves all kinds of traffic streams in the same way. In EDCA, due to its service differentiation mechanism, throughput of high priority traffic streams remains constant, as there is no effect of change throughput when the low priority traffics started to transmit.

The delay results are presented in Figs. 7 and 8. Figs. 7 and 8 show, that the voice performance is significantly improved via EDCA. When the background and best-effort traffic is started at 15 secs, it can also be seen, that the voice delay has increased manifolds in DCF (238 ± 23 ms) as compared to EDCA (95 ± 7 ms), which remains without change at the same time. High voice delay is not acceptable, which sometimes reaches 260 ms in DCF. The video delay in EDCA and ind DCF has approximately the same values (257 ms). It can also be seen, that the delay for video traffic has increased in DCF in comparison to EDCA, when all the access category traffic flows are existing in the network.
This paper discusses the performance evaluation of IEEE 802.11 and IEEE 802.11e with the help of simulation scenarios in Omnet++ and Inetmanet framework. It concludes also a performance comparison between the EDCA and the DCF mechanisms in order to support QoS requirements for different types of data traffic. The results show that all types of data traffic are treated equally in DCF which causes deficits in QoS support. On the other hand, the IEEE 802.11e treats all data traffics on the basis of their QoS requirements and priority. Two scenarios are simulated in order to compare IEEE 802.11 and IEEE 802.11e performance concerning to support the QoS. There are two performance metrics used to evaluate the performance of EDCA and DCF which are throughput and delay.

The scenarios results show that EDCA has a better performance and provides a service differentiation mechanism for different types of data traffic. The DCF serves all four traffic streams with the same priority and in the same way apart from their QoS requirements. The higher priority traffic streams are better served than lower priority traffic streams. The recommendation is to use the EDCA for streaming of VoWLAN, which emphasizes more advantages (higher throughput and lower delay) than DCF.

**Acknowledgement**

The author would like to thank Prof. Dr. K. Hänßgen for his valuable comments on the manuscript and for supporting this publication.

**References**


