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Abstract

In this paper, a medium access scheme called EDCF, which is adopted in an upcoming new standard IEEE802.11e to allow prioritized medium access for applications with QoS requirements, is described and discussed. Its performance is also evaluated via simulations.

1. Introduction

IEEE802.11 wireless LAN (WLAN) is a shared-medium communication network that transmits information over wireless links for all IEEE802.11 stations within the transmission range to receive. It is one of the most deployed wireless networks in the world and is high likely to play a major role in multimedia home networking and next-generation wireless communications. The architecture of IEEE802.11 standard includes the definitions of Medium Access Control (MAC) sublayer and Physical Layer (PHY). Its MAC layer has two access mechanisms: DCF (Distributed Coordination Function) and PCF (Point Coordination Function). DCF uses CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) protocol, and it is best known for asynchronous data transmission (or best-effort service). PCF uses a central-controlled polling method to support synchronous data transmission. Unlike DCF, the implementation of PCF is optional as stated in the standard [1]. 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 (AP) is needed to connect all stations to a Distribution System (DS), and each station can communicate with others through AP. DCF is the basic medium access mechanism for both ad hoc and infrastructure modes. In DCF mode, each station checks whether the medium is idle before attempting to transmit. If the medium has been sensed idle for a DIFS (Distributed InterFrame Space) period, the transmission can begin immediately. If the medium is determined to be busy, the station shall defer until the end of the current transmission. After deferral, the station will select a random backoff interval and shall decrement the backoff interval counter while the medium is idle. Once the backoff interval has expired, the station begins the transmission. More specifically, the station selects a random number called backoff time, in the range of 0 and CW (Contention Window). The backoff timer decrements the backoff time each time the medium is detected to be idle for an interval of one slot time. As soon as the backoff timer expires, the station can begin to transmit. If the transmission is not successful, a collision is considered to have occurred. In this case, the contention window is doubled, and a new backoff procedure starts again. The process will continue until the transmission is successful or discarded.

Video, audio, real-time voice over IP and other multimedia applications over WLAN with Quality of Service (QoS) support is very important for IEEE802.11 WLAN to be successful in wireless home networking and future wireless communications. Some high layer applications such as video, audio, email, and data transfer have different requirements in bandwidth, delay, jitter, and packet loss. However, in DCF mechanism of IEEE802.11, all the stations and data flows have the same priority to access medium. There is no differentiation mechanism to support the transmission of data streams with different delay requirements. So, the support of QoS for IEEE802.11 becomes critical for its success in multimedia applications. With the motivation in mind, IEEE 802.11 working group is currently developing a standard called IEEE802.11e, which enhances the current 802.11 MAC to support applications with QoS requirements. The upcoming IEEE802.11e standard adds a new function called HCF (Hybrid Coordination Function), which concurrently exists with basic DCF/PCF for backward compatibility and has both controlled contention-free and contention-based channel access methods in a single channel access protocol. The HCF combines functions from the DCF and PCF with some enhanced, QoS-specific mechanisms and frame subtypes to allow a uniform set of frame exchange sequences to be used for QoS transfers during both the CP (Contention Period) and CFP (Contention Free Period). The HCF uses a contention-based channel access method, called the enhanced DCF (EDCF) that operates concurrently with a controlled channel access mechanism based on a polling mechanism. In this paper, we only describe EDCF mechanism.

2. EDCF Mechanism

As stated in the previous section, DCF works as a listen-before-transmission scheme. In this mode, if the medium is determined to be idle for DIFS interval, the station transmits a packet immediately. Otherwise, a backoff procedure is started. The backoff time is a random number that lies between 0 and CW. The backoff time is computed as follows [1]:

Backoff Time = Random() * SlotTime (1)

Where Random() is a pseudorandom integer drawn from a uniform distribution over the interval [0,CW]. CW is an integer within the range of values of the PHY characteristics CWmin and CWmax, that is CWmin $\leq$ CW $\leq$ CWmax. SlotTime equals the value of the corresponding PHY characteristics. CW parameter shall take an initial value of CWmin. The CW shall take the next value in the series after each unsuccessful transmission until the CW reaches the value of CWmax. Once it reaches CWmax, the CW shall remain at the value of CWmax until it is reset. This improves the stability of the access protocol under high-load conditions. The CW shall be reset to CWmin after each successful attempt to transmit a packet. The set of CW values shall be sequentially ascending integer powers of 2, minus 1, beginning with a PHY specific CWmin value, and continuing up to CWmax value. The purpose of use of backoff procedure is to reduce the chances of collision by letting stations to select a random number as backoff time. It is seen that CWmin and CWmax are fixed for a given PHY. So, DCF doesn't differentiate the data traffic and stations. All stations and traffic classes have the same priority to access the wireless medium (WM). The QoS is not supported with the use of DCF.

In order to support applications with QoS requirements, some priority schemes have been proposed [2, 3]. The upcoming 802.11e standard is being defined to support QoS [4, 5]. Among the new features of 802.11e, the EDCF provides differentiated, distributed access to the wireless medium for 8 priorities for stations. EDCF channel access defines the access category (AC) mechanism that provides support for the priorities at the stations. Each station may have up to 4 ACs to support 8 user priorities (UPs). One or more UPs are assigned to one AC. A station accesses the medium based on the access category of the frame that is to be transmitted. The mapping from priorities to access categories is defined in Table 1 [5].

Priority (Same as 802.1D Priority)	Access Category (AC)	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

Table 1 – Priority to Access Category Mappings

Each AC is an enhanced variant of the DCF. It contends for TXOPs (Transmission Opportunities) using a set of EDCF channel access parameters. An AC with higher priority is assigned a shorter CW in order to ensure that in most cases, higher-priority AC will be able to transmit before the lower-priority ones. This is done by setting the contention window limits CWmin[AC] and CWmax[AC], from which the CW[AC] is computed, to different values for different ACs. For further differentiation, different IFS (Inter Frame Space) is introduced according to ACs. Instead of DIFS, an arbitration IFS [AIFS] is used. The AIFS is at least DIFS, and can be enlarged individually for each AC. Similar to DCF, if the medium is sensed to be idle in EDCF mechanism, a transmission can begin immediately. Otherwise, the station defer until the end of current transmission on the WM. After deferral, the station waits for a period of AIFS(AC) to start a backoff procedure. The backoff interval is now a random number drawn from the interval [1, CW(AC)+1]. Each AC within a single station behaves like a virtual station. It contends for access to the wireless medium and independently starts its backoff time after sensing the medium is idle for at least AIFS. Collision between ACs within a single station are resolved within the station such that the data frames from higher-valued AC receive the TXOP and the data frames from lower-valued colliding ACs behave as if there were an external collision on the WM. The timing relationship for EDCF is shown in Figure 1 [4].

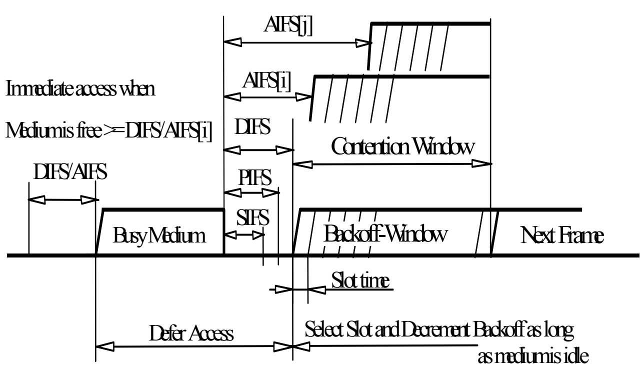

Figure 1: Timing Relationship for EDCF

The QoS support in 802.11e is realized with the introduction of Traffic Categories (TCs). MSDUs (MAC Service Data Units) are now delivered through multiple backoff instances within one station. Each backoff instance is parameterized with TC-specific parameters. The typical values for the parameters in QoS parameters set are defined in Table 2. A model of the reference implementation is shown in Figure 2 [5]. It illustrates a mapping from frame type or priority to access categories, the four queues and four independent channel access functions, one for each queue.

AC	CWmin	CWmax	AIFS
0	CWmin	CWmax	2
1	CWmin	CWmax	1
2	(CWmin+1)/2 - 1	CWmin	1
3	(CWmin+1)/4 - 1	(CWmin+1)/2 - 1	1

Table 2: Typical QoS Parameters

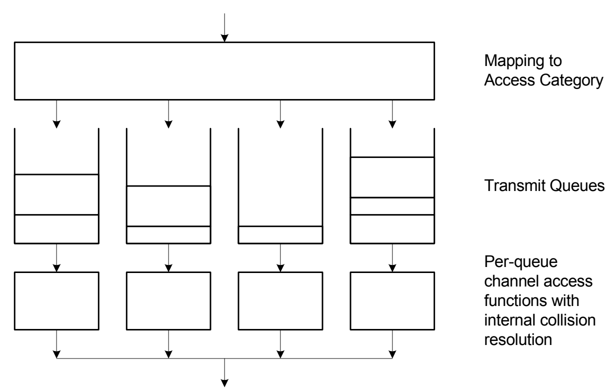

Figure 2: Reference Implementation Model

3. Simulation Results

A Simulation model was constructed using OPNET. In the simulation, four IEEE802.11 wireless stations with EDCF mechanism were configured into ad-hoc mode shown in Figure 3. Four stations remain stationary during the simulations. The simulation uses standard OPNET 802.11b PHY module with maximum data rate up to 11 Mbps to simulate the wireless medium [6]. While, the original 802.11

MAC was modified to support EDCF mechanism. In the simulation, we just simulated the EDCF access function and didn't consider other traffic parameters such as TXOPs. Any AC get an access to the medium, it transmits one packet and then release the channel for the next access contention. All PHY characteristics was according to 802.11b DSSS PHY parameters, in which CWmin= 31, CWmax=1023 and SlotTime=20 μs.

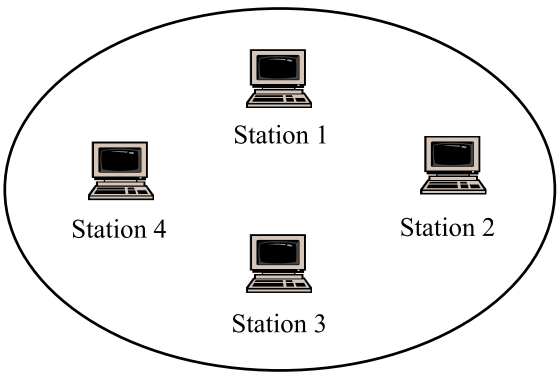

Figure 3. Simulation Scenario

All four traffic classes were fed into the MAC layer from higher layer, which are corresponding to AC(0), AC(1), AC(2) and AC(3) respectively. In the simulation, we assumed that each traffic class has the equal portion of the total data traffic in terms of the average number packets generated per unit time. The packets of AC(0), AC(1) and AC(2) were generated according to Poisson Process with a mean interarrival time equal to 0.0001 second, while AC(3) packets were generated at a constant rate to simulate a voice source.

Figure 4 shows the average medium access delays for different access categories in EDCF mechanism. As shown, access category (3) has the smallest average medium access delay, and access category (0) has the largest medium access delay. The horizontal coordinate represents the simulation time (minutes). In Figure 5, the throughputs for different ACs over the WLAN are shown. We can see that AC(3) has the highest value of throughput, while the throughput of AC(0) is lowest. These results are as expected since EDCF differentiates the traffic classes and supports priority access.

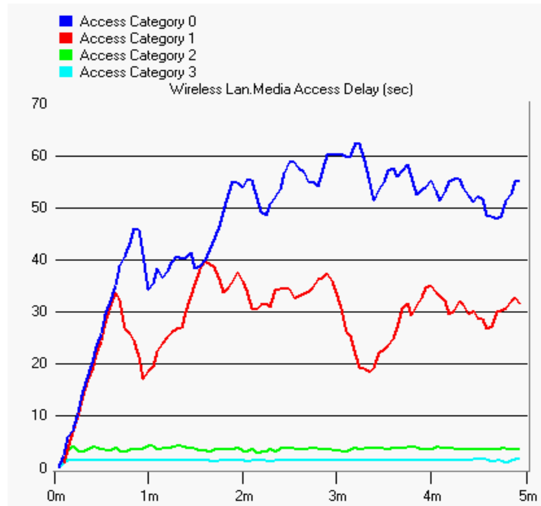

Figure 4. Medium Access Delay for Different ACs

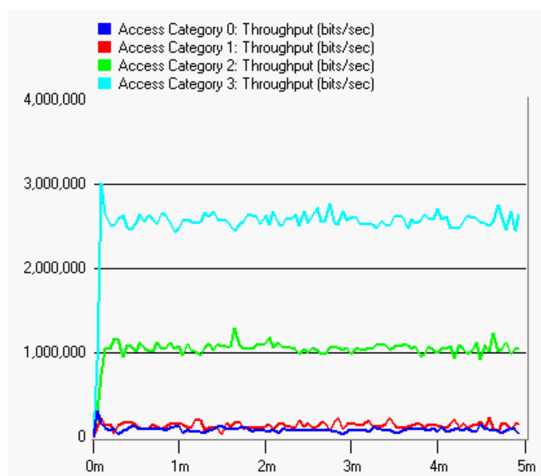

Figure 5. Throughputs for Different ACs

In order to compare with DCF function, an ad hoc IEEE802.11 wireless network with DCF mechanism was configured and simulated too. All the simulation parameters for the DCF scenario are exactly the same as the ones for the EDCF scenario except DCF is used instead of EDCF. In DCF scenario, the total data traffic is equal to sum of the 4 traffic categories of EDCF scenario. Figure 6 and

Figure 7 show the network average medium access delays and throughputs on the air for these two scenarios, respectively. The simulation results conclude that at this particular simulation condition, EDCF scenario has a little bit larger average medium access delay and a little bit smaller throughputs for all kinds of traffic. This can be explained. Since in EDCF mechanism, each AC functions like a virtual station for medium access, more collision will be expected for EDCF scenario.

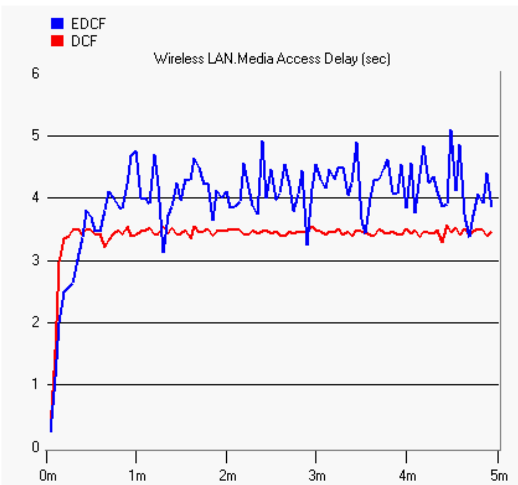

Figure 6. Network Medium Access Delays

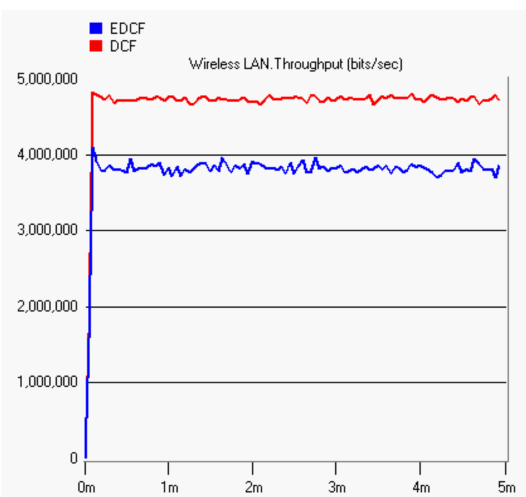

Figure 7. Network Throughputs for Different Access Schemes

4. Conclusions

In the paper, the EDCF mechanism for the upcoming standard IEEE802.11e is presented. A simulation was conducted. The simulation results show that EDCF works well for differentiated data services.

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