IEEE 802.11e

802.11e is an approved amendment to the IEEE 802.11 standard that defines a set of Quality of Service enhancements for wireless LAN applications through modifications to the Media Access Control (MAC) layer. The standard is considered of critical importance for delay-sensitive applications, such as Voice over Wireless IP and Streaming Multimedia. The amendment has been incorporated into the published IEEE 802.11-2007 standard. The original 802.11 MAC protocol was designed with two modes of communication for wireless stations.The first, Distributed Coordination Function (DCF), is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), sometimes referred to as “listen before talk.” A station waits for a quiet period on the network and begins to transmit data and detect collisions. DCF provides coordination, but it doesn’t support any type of priority access of the wireless medium.

The second, an optional mode, Point Coordination Function (PCF), supports time-sensitive traffic flows. Wireless access points periodically send beacon frames to communicate network identification and management parameters specific to the wireless network. Between the sending of beacon frames, PCF splits the time into a contention-free period (CFP) and a contention period (CP). With PCF enabled, a station can transmit data during contention-free polling periods.

However, PCF hasn’t been implemented widely because the technology’s transmission times are unpredictable. Since DCF and PCF do not differentiate between traffic types or sources, the IEEE developed enhancements in 802.11e to both coordination modes to facilitate QoS. These changes would let critical service requirements be fulfilled while maintaining backward-compatibility with current 802.11 standards.

The enhancement to DCF – Enhanced Distribution Coordination Function (EDCF) – introduces the concept of access categories. Each station has four kinds of access categories, or priority levels to differentiate the channel access probability among different traffic sources. With EDCF, high priority traffic has a higher chance of being sent than low priority traffic: a station with high priority traffic waits a little less before it sends its packet, on average, than a station with low priority traffic. This is accomplished by using a shorter contention window (CW) and shorter Arbitration Interframe Space (AIFS).

Each of the access categories (AC) contends for the medium with the same rules as the standard DCF (i.e. wait until the channel is idle for a given amount of interframe space, IFS, and then access/retry following exponential backoff rules). The access probability differentiation is provided by using i) different AIFSs instead of the constant distributed IFS (DIFS) used in DCF, and ii) different values for the minimum/maximum CWs to be used for the backoff time extraction. Then, each AC is specified by the values *AIFS*[*AC*], *CWmin*[*AC*], and *CWmax*[*AC*]. The *AIFS*[*AC*] values each differ for an integer number of backoff slots. In particular,

$$AIFS[AC] = AIFSN[AC] \cdot aSlotTime + aSIFSTime$$

where *AIFSN*[*AC*] is an integer greater than 1 for normal stations and greater than 0 for APs. Table 1 shows the default values of the channel access parameters defined in EDCA for the four ACs (BK = background, BE = best effort, VI = video, VO = voice). Note that these parameters are not fixed: in each beacon frame, the access point (AP) broadcasts the values chosen for each AC. Indeed, these values may also be dynamically adapted according to network conditions. Obviously, the smaller the *AIFSN*[*AC*] and *CWmin*[*AC*], the higher the probability of winning the contention with the other ACs. Separate queues are maintained in each station for different ACs shown in Figure 1, and each behaves as a single enhanced DCF contending entity. When more than one AC of the same station expire its backoff counter, a virtual collision occurs, and the highest-priority packet among the colliding ones is selected for actual transmission on the radio channel.

Table 1: EDCA Default Settings

Priority	Access Catagory	*CWmin*	*CWmax*	*AIFSN*
lowest	Background (AC_BK)	aCWmin	aCWmax	7
	Best Effort (AC_BE)	aCWmin	aCWmax	3

	Video (AC_VO)	aCWmin/2	aCWmin	2
highest	Voice (AC_VI)	aCWmin/4	aCWmin/2	2

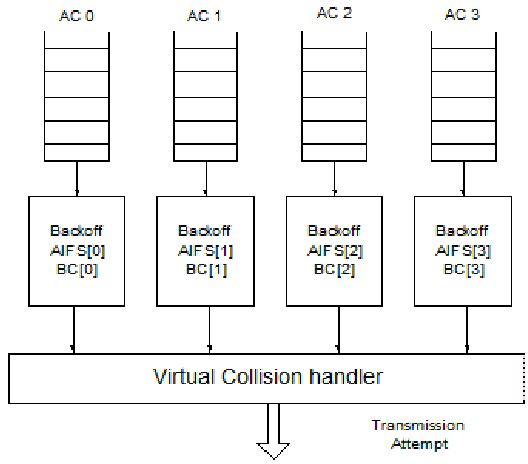

Figure 1: ACs and Virtual Collision

Another way 802.11e aims to extend the polling mechanism of PCF is with the Hybrid Coordination Function (HCF). The HCF controlled channel access (HCCA) works a lot like PCF. However, in contrast to PCF, in which the interval between two beacon frames is divided into two periods of CFP and CP, the HCCA allows for CFPs being initiated at almost any time during a CP. This kind of CFP is called a Controlled Access Phase (CAP) in 802.11e. A CAP is initiated by the AP whenever it wants to send a frame to a station or receive a frame from a station in a contention-free manner. In fact, the CFP is a CAP too. During a CAP, the Hybrid Coordinator (HC), which is also the AP, controls the access to the medium. During the CP, all stations function in EDCA.

A second difference with the PCF is that Traffic Class (TC) and Traffic Streams (TS) are defined. This means that the HC is not limited to per-station queuing and can provide a kind of per-session service. Also, the HC can coordinate these streams or sessions in any fashion it chooses (not just round-robin). Moreover, the stations give info about the lengths of their queues for each Traffic Class (TC). The HC can use this info to give priority to one station over another, or better adjust its scheduling mechanism.

Another difference is that stations are given a transmission opportunity (TXOP): they may send multiple packets in a row, for a given time period selected by the HC. During the CP, the HC allows stations to send data by sending contention free (CF)-Poll frames. HCCA is generally considered the most advanced (and complex) coordination function. With the HCCA, QoS can be configured with great precision. QoS-enabled stations have the ability to request specific transmission parameters (data rate, jitter, etc.), which should allow advanced applications like VoIP and video streaming to work more effectively on a Wi-Fi network.

HCCA support is not mandatory for 802.11e APs. In fact, few (if any) APs currently available are enabled for HCCA. Implementing the HCCA on end stations uses the existing DCF mechanism for channel access (no change to DCF or EDCA operation is needed). Stations only need to be able to respond to poll messages. On the AP side, a scheduler and queuing mechanism is needed.

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