Chapter 1

Introduction

The success in wireless technology brings great convenience toward life. Without the constraint of wired connection, people could surf the Internet everywhere with their portable gadgets, such as personal digital assistant (PDA) and laptop. The issue of quality of service (QoS) becomes vital because of the furious growth of multimedia applications. More and more people go online not only simply for web browsing, but also for playing games, watching video, or making a call (Voice over IP). Those applications have different kinds of requirement of delay, bandwidth, and loss ratio. When it comes to wireless network, the problem becomes more serious. The instability of radio link results in unpredictable network conditions, which in turn leads to high packet loss ratio and low transmission rate. In addition, to reduce unnecessary energy consumption is another challenge since most of the wireless devices use batteries as the power source instead of continuous electricity supplies.

The most prevalent wireless technology would be IEEE 802.11 [1], which was completed in 1999. However, there is no consideration for QoS in original IEEE 802.11 standard. In order to satisfy the demand of various applications, IEEE 802.11 Task Group E was established in order to define QoS mechanisms based on original 802.11 standard. The QoS supplement to 802.11 standard is called 802.11e [2], which is still in draft phase currently. The thesis proposed two solutions to improve the performance of 802.11 Point Coordination

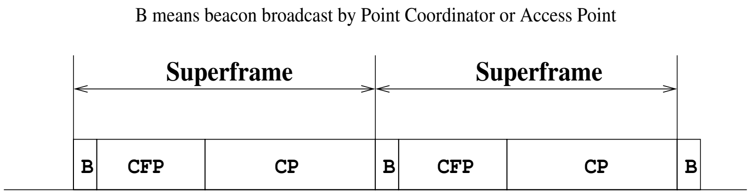

Figure 1.1: Structure in IEEE 802.11 MAC

Function (PCF) and 802.11e Enhanced Distributed Channel Access (EDCA).

1.1 IEEE 802.11

IEEE 802.11 is the most popular specification for wireless LAN technology. It provides 1M and 2Mbps transmission rate in the 2.4GHz band. Following original 802.11 standard, 802.11b, 802.11a, and 802.11g yield more bandwidth by different radio techniques and varied frequency. Despite a family of various supplements to 802.11, the operations for medium access control (MAC) is the same among all of them. There are two modes in IEEE 802.11 MAC: one for centralized control, which is called as Point Coordiation Function (PCF), while the other one for distributed contention, which is called Distributed Coordination Function (DCF). The 802.11 MAC process could be divided into superframes. Every single superframe is composed of two intervals: Contention Free Period (CFP) in which PCF takes place and Contention Period (CP) in which DCF occurs. Fig. 1.1 shows the interchange of CFP and CP during a superframe.

1.1.1 Point Coordination Function (PCF)

Operations in 802.11 PCF

PCF is a contention-free methodology for different wireless stations to access the transmission medium. The dominant component in PCF operation is *Point Coordinator (PC)*, which

1.1.1. Point Coordination Function (PCF)

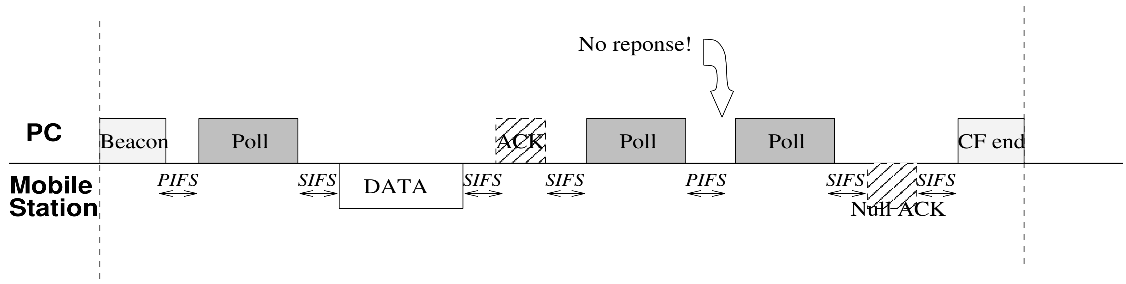

Figure 1.2: IEEE 802.11 PCF process

usually resides in the access point (AP). *Target Beacon Transmission Time (TBTT)* is the time when PC is supposed to send out beacon packet. At TBTT, PC could grab the medium and claim that CFP begins if channel is idle for *Point InterFrame Space (PIFS)*. PC maintains a polling list to query each station from the list whether it has packet to send. A station has no right to access the shared medium unless it is polled by PC. When receiving the poll from PC, a station could transmit one buffered frame. If the polled station does not have any frame, it will reply a *Null Acknowledgement* to PC. Provided that there is no response from a polled station (may due to the loss of poll or data frame from polled station), the PC will then ask the next candidate from the polling list after an interval of PIFS. *aMaxCFPDuration* is the predefined maximum duration for CFP. The PC will terminate the CFP if the interval is longer than *aMaxCFPDuration* or all the stations on the list are already polled. By receiving a *CF-end* frame broadcast by PC, all the attached stations will enter into CP and starts the DCF operations. Fig. 1.2 illustrates the PCF operations.

The QoS issues in 802.11 PCF

Although PCF is more suitable for bandwidth and delay stringent traffic than DCF, it has deficiency. The last CP operation may occupy CFP time. As Fig. 1.3 presents, the PC will start sensing the channel at TBTT. It could not claim that CFP starts until the medium is idle for PIFS. However, the medium may be busy at TBTT because of the transmission of the

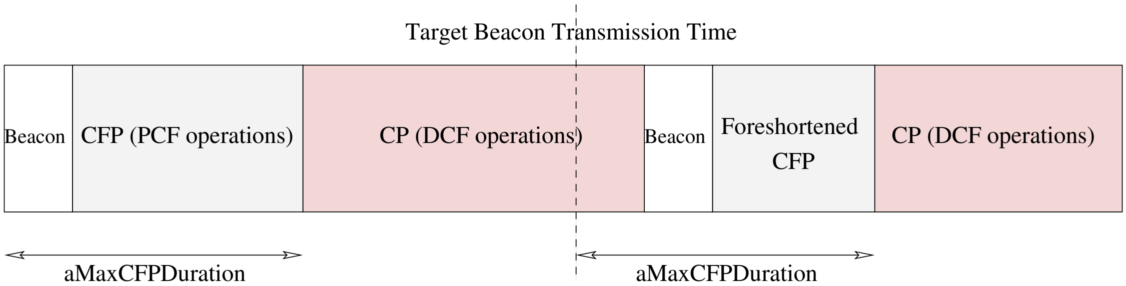

Figure 1.3: Foreshortened PCF

last DCF frame. The longest delay of CFP can be the transmission time of maximum packet and its acknowledgement frame. This will reduce the effective duration of PCF because of the limitation of CFP maximum interval. The shrunk CFP is called *foreshortened CFP*. The phenomenon will deteriorate the quality of high priority traffic because of the lagged PCF operation. Besides, it is hard to predict when the PCF could begin, which makes PCF scheduling more challenging.

Since PCF is polling oriented, it has additional overhead for poll frame. Every single data transmission will involve an extra poll frame, which decreases the overall effective bandwidth. The PCF efficiency and the traffic quality is dominated by the scheduling method. Nevertheless, IEEE 802.11 standard did not declare a specific scheduling algorithm, and little literature work has focused on this.

1.1.2 Distributed Coordination Function (DCF)

Operations in 802.11 DCF

The IEEE 802.11 DCF is a distributed MAC protocol. A station needs to listen to the channel before it can transmit. If the channel is idle longer than *Distributed Inter Frame Space (DIFS)*, the station can grasp the channel and initiate the transmission immediately. If the channel is busy, on the other hand, the station has to wait until the channel becomes idle

1.1.2. Distributed Coordination Function (DCF)

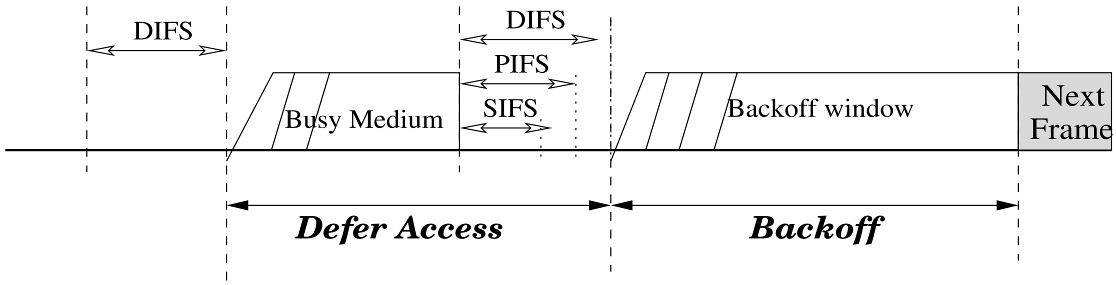

Figure 1.4: IEEE 802.11 DCF operation

longer than DIFS again. It then starts *backoff* process. The station will randomly choose a number between 0 and the *Contention Window (CW)* as its initial backoff timer. The value of *CW* is initialized as CW_{min} at the very beginning. Whenever a collision occurs, the *CW* will be doubled until the it becomes CW_{max}. A successful transmission will reset the *CW* as CW_{min}. The backoff timer elapses when the medium is idle. If the medium becomes busy anytime during the backoff process, the backoff timer will be frozen until the channel is idle longer than DIFS again. The station can not transmit until the backoff timer expires. The DCF is also known as *Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)*. In DCF, all stations have equal opportunity in channel access.

In IEEE 802.11, there are three different kinds of inter frame space: *Short Inter Frame Space (SIFS)*, *Point Inter Frame Space (PIFS)*, and *Distributed Inter Frame Space (DIFS)*. $SIFS$ is the shortest one among them. It is used to seperate a sequence of continuous frame transmission. For example, after receiving a frame, the receiver will reply an acknowledgement to the sender after $SIFS$. Because $SIFS$ is the shortest interval, no other stations could access the medium during the process. $PIFS$ is for PCF, while $DIFS$ is for DCF. Since $PIFS$ is shorter than $DIFS$, PC is more likely to win the medium and start the CFP at the beginning of every superframe. So PCF has higher priority than DCF in IEEE 802.11. Fig. 1.4 shows the operations in DCF and the relationship between $SIFS$, $PIFS$, and $DIFS$.

The QoS issues in 802.11 DCF

There is no differentiation among various kinds of application. Every one has the same opportunity in channel access. DCF could not meet the need of a wide variety of multimedia application nowadays. In addition, DCF can be inefficient when load is high. The operaitons in DCF is contention based; that is, all stations contend the medium independantly. As the traffic is intense, most part of the bandwidth is wasted on collision or backoff stage. Stations could hardly get the transmission opportunity in the situation. Compared with PCF, DCF could not provide QoS guarantees for bandwidth or delay stringent application, and is only suitable for best effort traffic.

1.2 IEEE 802.11e

In order to overcome all the QoS shortcomings in IEEE 802.11 standard, IEEE 802.11 Task Group E was established in order to define QoS mechanisms based on original 802.11 standard. The amendment is called IEEE 802.11e and it is still in draft phase currently. 802.11e is fully compatible with original 802.11 standard. The MAC mechanism in 802.11e is called *Hybrid Coodination Function (HCF)*, which incorporates two schemes: *HCF Controlled Channel Access (HCCA)* and *Enhanced Distributed Channel Access (EDCA)*.

1.2.1 HCF Controlled Channel Access (HCCA)

Similar to *IEEE 802.11 PCF*, $HCCA$ is polling based. The major component in $HCCA$ is *Hybrid Coordinator (HC)*, which usually resides in the *Access Point (AP)*. When channel remains quiet longer than $PIFS$, HC could grab the medium and claim that the CFP or *Controlled Access Phase (CAP)* begins. Different from PCF in 802.11 standard, however, CAP could occur at äny timeẅhen medium stays idle for $PIFS$ without the limitation of one time occurrence in every superframe. As Fig. 1.5 shows, CAP could occur even during

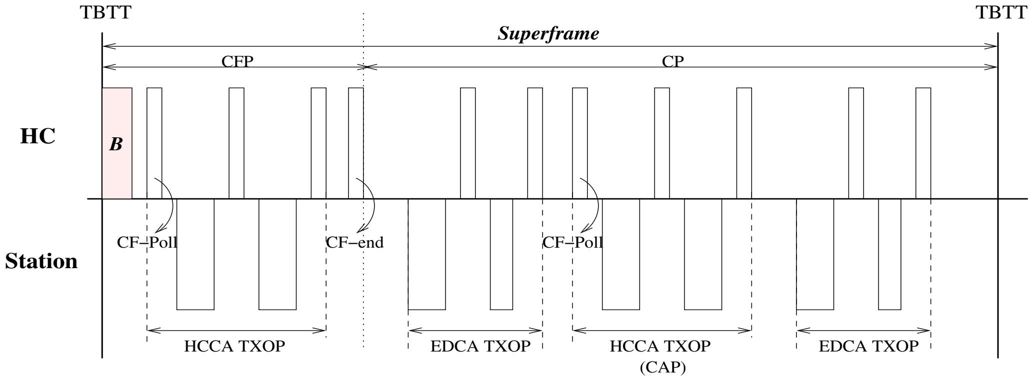

Figure 1.5: IEEE 802.11e HCF operation

the CP. A CAP ends when the HC does not reclaim the channel after a duration of $PIFS$ after the end of a $TXOP$. The design of CAP enables HC to provide more reliable service quality for high priority traffic. HC has more flexibility in CAP and CP scheduling.

The IEEE 802.11e defines *Transmission Opportunity (TXOP)*. It is an interval in which a station can continuously transmit a sequence of frames without contending the channel if the station successfully gain the channel access. Compared with original 802.11 standard, a station is only allowed to convey a frame when gaining the transmission opportunity. If a $TXOP$ is acquired by distrbuted contention, it is called *EDCA TXOP*. On the other hand, if a $TXOP$ is assigned by the HC, it is called *HCCA TXOP*. The invention of $TXOP$ could highly improve both the utilization and efficiency of wireless medium because less bandwidth is wasted on channel contention.

1.2.2 Enhanced Distributed Channel Access (EDCA)

The *802.11e EDCA* is similar to *802.11 DCF*. However, the $EDCA$ differentiates traffic into four different *Access Categories (ACs)*. They are AC_VO (for voice traffic), AC_VI (for video traffic), AC_BE (for best effort traffic), and AC_BK (for background traffic). AC_VO possesses the highest priority, while AC_BK is the most inferior one among the

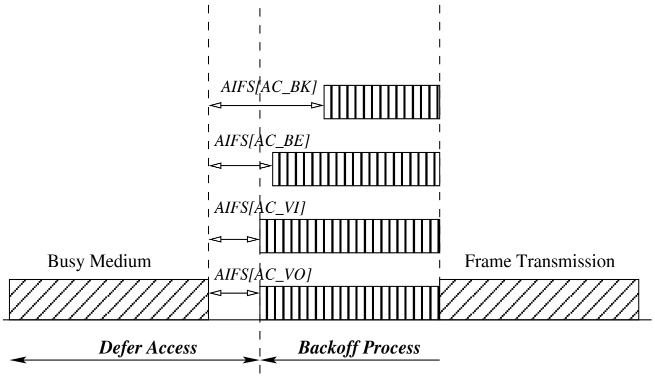

Figure 1.6: IEEE 802.11e EDCA operation

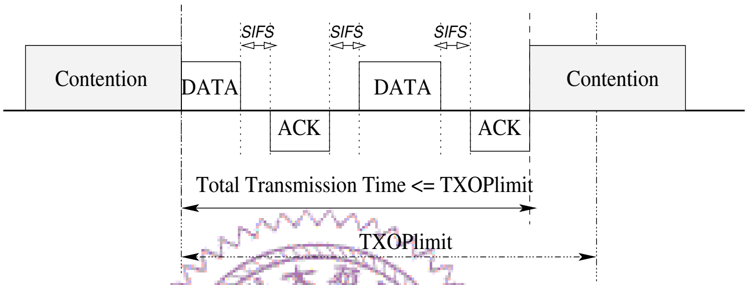

Figure 1.7: The Contention Free Burst (CFB) operation

four. Each AC has its own buffered queue and parameter set. The *EDCA Parameter set* includes *minimum Contention Window size* (CW_{min}), *maximum Contention Window size* (CW_{max}), *Arbitration Inter Frame Space (AIFS), and Transmission Opportunity limit* ($TXOP_{limit}$). CW_{min} and CW_{max} both determine the CW size. CW is set as CW_{min} at the very beginning. A failed transmission will double CW until it equals CW_{max}. Asuccessful one will reset CW to CW_{min}. Instead of $DIFS$, a station needs to defer for its corresponding $AIFS$ interval. It is obvious that smaller CW_{min}, CW_{max}, and $AIFS$ will lead to better chance of gaining the medium. Fig. 1.6 demonstrates the operations in *802.11e EDCA*.

In $EDCA$, users are allowed to transmit multiple frames of the same AC continuously within the time limit defined by $TXOP_{limit}$. This is called *Contention Free Burst (CFB)*. Comparing with DCF, in which only one frame exchange is permitted every time when gaining the channel, the CFB in $EDCA$ could improve the medium utilization because less bandwidth is wasted on contention, and more bandwidth is for effective data transmission. In 802.11e draft, higher priority ACs have longer $TXOP_{limit}$, while lower priority ACs have shorted $TXOP_{limit}$. The operations of CFB are as shown in Fig. 1.7.