Tribhuvan University
Institute of Science and Technology

"Study of IEEE 802.11e MAC based on EDCA and HCCA for QoS support"

Project Work
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Central Department of Computer Science and Information Technology Kirtipur, Kathmandu, Nepal

In partial fulfillment of the requirements for the Master's Degree in Computer Science and Information Technology

by
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Supervisor's Recommendation

I hereby recommend that this project work prepared under my supervision by **Mr. Tojendra Rokaya** entitled **"Study of IEEE 802.11e MAC based on EDCA and HCCA for QoS support"**in partial fulfillment of the requirements for the degree of M. Sc. in Computer Science and Information Technology be **processed** for the evaluation.

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LETTER OF APPROVAL

We certify that we have read this Project Work and in our opinion it is satisfactory in the scope and quality as a dissertation in the partial fulfillment for the requirement of Masters Degree in Computer Science and Information Technology.

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Student's Declaration

I hereby declare that I am the only author of this work and that no sources other than the listed here have been used in this work.

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Tojendra Rokaya

ABSTRACT

Providing QoS support in 802.11 WLAN protocols and MAC functions is challenging as current 802.11 standard does not take QoS support into account. Both the 802.11 MAC layer and the physical (PHY) layer are designed for best-effort data transmission. With this given limitation, this project work seeks to achieve comprehensive view of the 802.11e WLAN and critically analyse QoS limitations and issues in 802.11e WLAN. This p tends to evaluate and analyse QoS techniques and enhancements of MAC layer protocol. The important classes of QOS guarantee's which can be used in WLAN are proposed which are differentiation serving system, information extracting system based on PHY layer, resource reserving and CAC in MAC layer and IEEE 802.11 parameters tuning system in order to meet the QoS requirements. However, finding the right set of MAC parameters and the correct QoS mechanisms to use, are still an open issue. Simulations were performed with a scenario with voice stations, video stations and data stations for both DCF and the EDCF. Comparisons were made in the aggregated throughput of each traffic type stations. Voice performance and video delay performance were significantly observed to be improved via the EDCF. With the observed delay and error performance, it is expected that the EDCF can support real-time applications with voice and video traffic with a reasonable quality of service in certain environments.

Keywords:

Quality of Service, Distributed Coordination Function, Hybrid Coordination Function, Enhanced Distributed Coordination Function, HCF Controlled Channel Access, Point Coordination Function.

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LIST OF ABBREVIATIONS

Abbreviation	Designation
AC	Access Category
AC VO	Access Category Voice
AC VI	Access Category Video
AC BE	Access Category Best Effort
AC BK	Access Category Back Ground
AIFS	Arbitration Inter Frame Space
AP	Access Point
BO	Back off
CSMA/CA	Carrier Sense Multiple Access / Collision Avoidance
CW	Contention Window
CWmax	Contention Window Maximum
CWmin	Contention Window Minimum
DCF	Distributed Coordination Function
DIFS	DCF Inter Frame Space
DSSS	Direct Sequence Spread Spectrum
EDCA	Enhanced Distributed Channel Access
EDCAF	Enhanced Distributed Channel Access Function
HCCA	HCF Controlled Channel Access
HCF	Hybrid Coordination Function
IBSS	Independent Basic Service Set
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
MAC	Medium Access Control
Mbps	Mega bit per second
OFDM	Orthogonal frequency-division multiplexing

PCF	Point Coordination Function
QoS	Quality of Service
SIFS	Short Inter Frame Space
STA	Station
WLAN	Wireless Local Area Network

CHAPTER 1: INTRODUCTION

1.1. Background

In past few years, IEEE 802.11 Wireless local Area network (WLAN) has been known as one of the most current wireless technology ubiquitously and plays a major role in next-generation wireless communication network. Due to simplicity of the wireless network, it can be found in many organisations, institutions and public places.

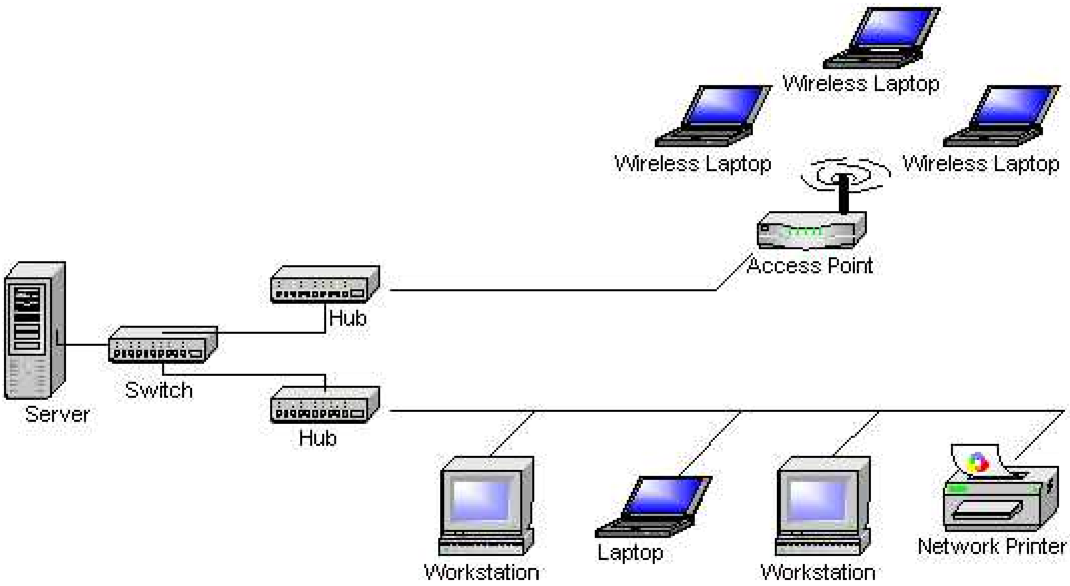

Figure 1: Example of a standard wireless LAN topology

1.2. Components of IEEE 802.11 Network Architecture

The IEEE 802.11 standard has two basic components: Stations (STA) and Access Points (AP). Basic Service Set (BSS) is the basic building block, which can include several STAs and APs. These basic components are able to communicate wirelessly with all others belonging to the same BSS.

There are two main types of wireless network configuration: ad-hoc mode and infrastructure mode.

1.2.2. Ad-hoc Mode

This kind of WLAN is the simplest form of communication possible involves only STAs (at least two), that is helpful to create small dynamic networks and have similar limitations as wired peer to peer networks. In ad hoc mode, all wireless stations within the communication range can communicate directly with each other. Whenever STAs are able to communicate directly, such network will be referred to as Independent BSS (IBSS).

1.2.3. Infrastructure Mode

In infrastructure mode, for the network cards to communicate, it needs one or more access points. The access point receives, buffers, and transmits data between the wirelesses LAN. An Access Point is needed to connect all stations to a Distribution System (DS), and each station can communicate with others through the AP. In the Infrastructure mode of operation, each AP is in charge of managing the STAs belonging to its BSS. Prior to be able to exchange data frames, a STA has to successfully Authenticate with the AP, and then Associate to it.

Access Point is also called Base Station. A Basic Service Set (BSS) is composed of a base station and several stations. Several BSSs can be interconnected through the APs making an Extended Service Set (ESS). Also, any LAN can be interconnected to any BSS (through a portal), making also an ESS. Distribution System (DS) is the architectural component used to interconnect BSSs.

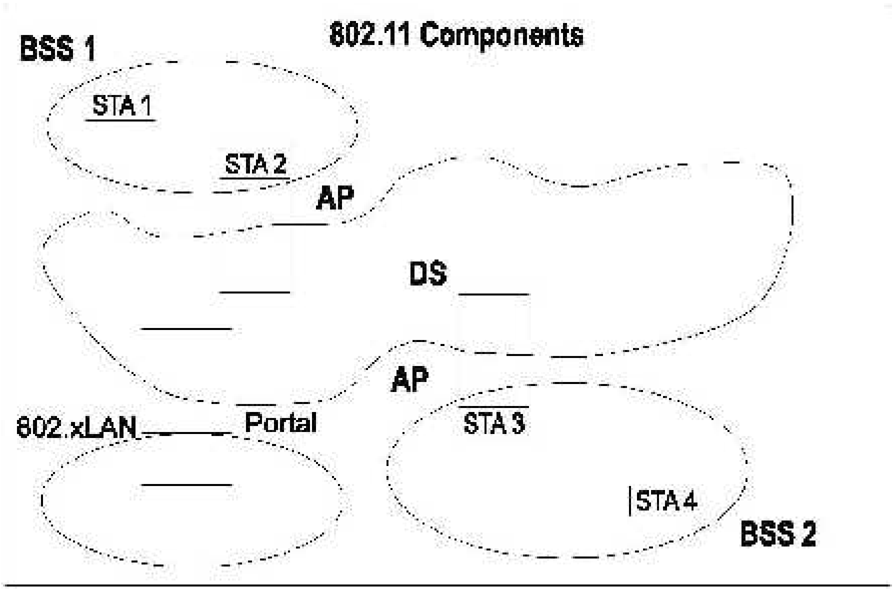

Figure 2: 802.11 Components

The following are the IEEE 802.11 wireless network standards.

Standard	Description
IEEE 802.11	Offers 1 or 2 Mbps transmission in 2.4 GHZ band, uses frequency hopping spread spectrum (FHSS) or direct sequence spread spectrum (DSSS)
IEEE 802.11a	Transmit at data rates up to 54 Mbps in the 5-GHz, uses orthogonal frequency division multiplexing (OFDM) encoding scheme
IEEE 802.11b	Transmit at data rates up to 11 Mbps in the 2.4-GHz ISM (Industrial, Scientific and Medical) band, uses only DSSS

Standard	Description
IEEE 802.11e	Improve the 802.11 Medium Access Control (MAC) in order to enhance and deal with Quality of Service, offer classes of service. These enhancements are supposed to offer the quality for multimedia services like audio, video.
IEEE 802.11f	Develop for an Inter-Access Point Protocol (IAPP) that offers the ability to get multi-vendor Access Point interoperability to support IEEE WLAN.
IEEE 802.11h	Improve the 802.11 Medium Access Control (MAC) standard and 802.11a PHY in the 5GHz band.
IEEE 802.11i	Develop the 802.11 Medium Access Control (MAC) in order to improve security and authentication mechanisms

Table 1: Different IEEE 802.11 standard.

1.3. Quality of Service

To support quality of service for delay and timing sensitive applications in WLAN, it needs to provide sufficient priority (i.e. bandwidth, delay, jitter, error rate) which is vital by real-time and interactive applications, like audio, video, and to improve loss features.

a) Throughput or bandwidth: In WLAN, there is not sufficient capacity to transfer large chunks of data due to physical limitations and inadequate available bandwidth so as to meet the QoS requirements. Therefore, it is not able to get the same data rates.

b) Delay or latency: sometimes when the packets arrive at the destination end, it takes a long time due to heavy traffic of data and takes a fast, direct route. Hence, delay is difficult to predict.

c) Delay jitter: whenever the packets from source arrives at the destination with various delays, this difference in delay is called delay jitter which can badly influence the quality of streaming audio or video.

d) Loss or error rate: when packets arrive from source to destination, it might be lost or corrupted before it reaches the destination. The receiving end needs to detect whether the packet is dropped or incomplete and request he sender to retransmit it.

1.4. Problem Statement

The number of multimedia applications has increased tremendously, to acquire voice, audio and high speed video when transferring between client and server. Multimedia applications require a certain quality of service (QoS) support such as guaranteed bandwidth, delay, throughput, jitter, and error rate. Guaranteeing those QoS requirements is a challenging task with regard to 802.11 WLAN protocols and Medium Access Control (MAC) functions.

Providing such QoS support in 802.11 is challenging since the current 802.11 standard does not take QoS support into account [1] both the 802.11 medium access control (MAC) layer and the physical (PHY) layer are designed for best-effort data transmission. The IEEE 802.11 WLAN standard covers both the MAC sub-layer and the PHY layer of the open system interconnection (OSI) network reference model [1].

1.5. Objectives

The objective of this project work is:

- To achieve comprehensive view of the 802.11e WLAN and analyse QoS limitations and issues in 802.11e WLAN.
- To analyse the MAC layer protocol for providing QoS in 802.11e.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction to IEEE 802.11 MAC Layer

The Data link layer of OSI model consists of two sub layers, logic link control (LLC) and Media Access Control (MAC) layer. The function of MAC is to transfer data to and from one Network Interface Card (NIC) to another across a shared channel. It uses MAC protocols to make sure that the signals sent from various stations across the same channel do not collide.

The main purpose of the IEEE 802.11 MAC layer is to provide reliable data services to the higher layer protocols. A frame exchange protocol is defined to accomplish this goal. The frame is sent from the source to destination and if the frame is received successfully acknowledgement (ACK) is sent from destination to the source. There is Frame Check Sequence (FCS) in the MAC layer which is IEEE 32 bit CRC that checks for each frame received at the MAC. The frame is retransmitted if the source does not receive any acknowledgement from the destination or FCS fails. This method deals with the error conditions such as the interference in the wireless medium and data integrity in the link layer.

In order to boost the strength of the protocol and address the hidden terminal problem, an optimal Request-To-Send / Clear- To-Send (RTS/CTS) mechanism is defined in MAC layer. It has a four-way handshaking mechanism, in which STA sends RTS frame to the destination before sending any MAC Service Data Unit (MSDU). Once a correct RTS is received, the destination responds with CTS and then the source can send the MSDU after receiving the corresponding CTS response. All the neighbouring STAs can update their internal timer called Network Allocation Vector (NAV) and postpone any transmission until their timer expires which is all based upon the information of RTS/CTS frames that contains the information on the duration of MSDU/ ACK transmission. The CTS will still be capable of receiving the response from the destination STA and renew its NAV accordingly even if the hidden STA cannot listen to the RTS from the source STA. This method keeps watching the transmission between the STAs against unpredicted transmission from the hidden STAs.

The interaction of MAC layers is essential with physical layer to top of the application layer as shown in figure

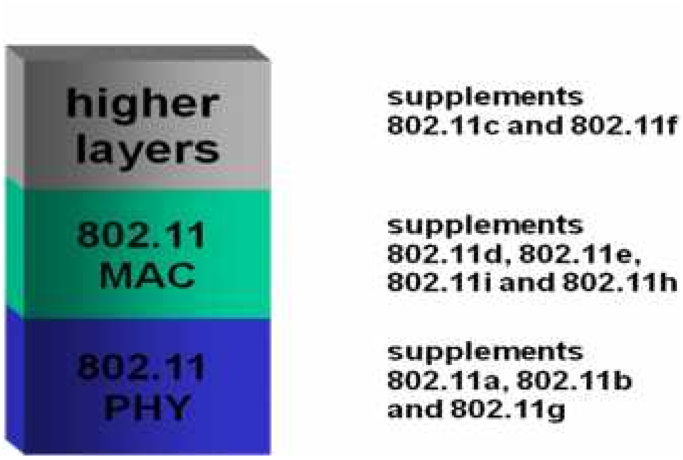

Figure 3: 802.11 standards

2.1.1. PHY and MAC Layers Interaction

One of the most important parameter of the Physical Layer is Signal to Noise Ratio (SNR) [2]. SNR concerns the useful rate which has dependency on data packet computing. Using Bit Error Rate (BER) it can be calculated the state of the medium and the Quality but BER is only calculated at the receiving station. Mathematically, it can be interpreted SNR as:

$$SNR = \frac{\text{Emitted/received signal power}}{\text{Noise power}}$$

2.1.2 MAC and Network Layers Interaction

In TCP/IP networks, DiffServ architecture is used to ensure the different types of services to support multimedia based applications or real time applications. To make identification for the packets in networks, packets are classified and marked. Traditional MAC sub layer is not aware of the classifications as it supposes that traffic flows are indifferent.

With the motivation that the MAC level to be able to support the QoS, in this project work I propose to jointly exploit information obtained from the physical and network layer and hence deliver packets based on the priorities following the QoS requirements.

To achieve the above mentioned problem frames in the WLAN must be differentiated according to the priority classes which are indicated by higher layers in order to ensure point to point QoS which is based on DiffServ. When a data frame MSDU arrives at the MAC sublayer, it is further encapsulated in a MPDU (MAC Protocol Data Unit) by adding “MAC Heading” field and of a "Frame Control Sequence" field [3].

The basic 802.11 MAC protocol [1] defines two transmission modes for the data packets: the Distributed Coordination Function (DCF), based on CSMA/CA (Carrier Sense Multiple Access/ Collision Avoidance), and the Point Coordination Function (PCF), where the AP controls all the transmissions based on a centralised polling scheme.

2.2. Distributed Coordination Function (DCF)

The existing IEEE 802.11 protocols make use of the distributed coordination function (DCF) access method for both ad hoc and infrastructure mode. It implements a "listen before talk scheme", which is based upon Carrier Sense Multiple Access (CSMA). The station first checks if the wireless medium is idle, if it is not, the station initiates a back-off timer with a random back-off interval. In DCF, the decision making process is distributed among the all stations because each station decides separately when to access the medium.

In the implementations, the modulation technique used for radio transmission is Direct Sequence Spread Spectrum (DSSS) in which the signal is deliberately spread over the channel bandwidth. This operates on license free ISM Band (2.4 – 2.4835 GHz). These frequencies are also utilized by other technologies like Bluetooth Devices, Cordless Phones etc as a result there likely to be some interference. The solution for this would be an effective network planning so it can meet the standard performance especially when employing real time applications like internet telephony and on demand videos. In order to access the wireless medium, DCF offers equal chance for each device, but it operates well only in traditional data applications. Since the users are not aware of the fact of sharing the wireless medium with others, these applications are not sensitive to latency and jitter. On the contrary, video, gaming and other applications are not able to tolerate the bandwidth fluctuations, which leads to insufficiency of the fairness- access mechanism, provide by DCF.

In CSMA/CA, once a station detects that the wireless medium is idle for a minimum duration called DCF Interframe Space (DIFS, which is 50 µs for 802.11b), its back-off counter starts to decrease every time the medium is detected idle for an interval of one slot time (20 µs in 802.11b). When back-off timer expires and the medium is still free, the station starts to send out MAC Service Data Units (MSDUs) of arbitrary lengths.

In response to the reception of a frame, the receiver acknowledges by sending ACK Frame after a short time called Short Interframe Space (SIFS) typically 10 Micro Seconds for Wi-Fi. The SIFS is relatively shorter than DIFS (SIFS + 2 Slot time) as a result ACK Frame is protected from collision from other stations' contention. After the successful transmission, the transmitting station performs another random back-off even if there is no pending MSDU to be delivered which is commonly referred as "Post Back-off". Post Back-off process ensures that there is at least one back-off interval between two consecutive MSDU transmissions. If the corresponding ACK frame is not received after the data transmission, the frame is retransmitted after another random back off and yet goes another contention process.

Backoff Time = Random () * SlotTime (1)

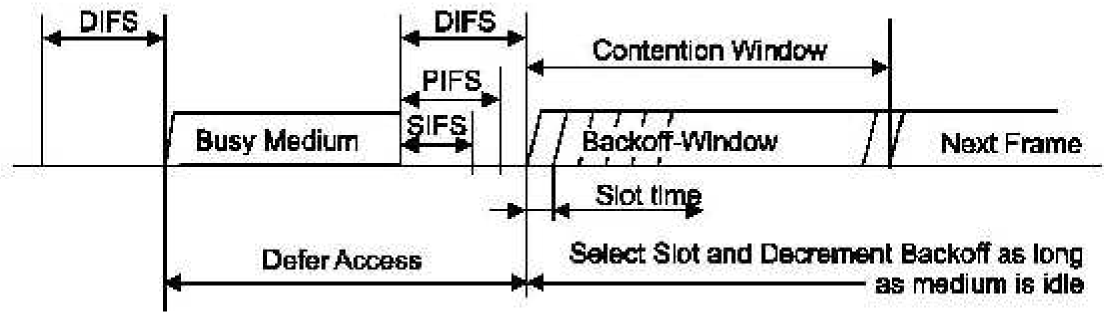

Figure 4: IEEE 802.11 DCF Basic Access Method

If CW is the Contention Window, an integer within the physical characteristics CWmin and CWmax, generally 31 and 1024 for 802.11b then the initial value of the back-off counter is chosen from a uniform distribution over the interval (0, CW). Initially the value for Contention Window is CWmin, whereas for each unsuccessful transmission the value for CW increases in power of 2, after CW has reached the maximum value CWmax the process again starts from CWmin for the next frame. The back-off process is suspended if the channel is sensed busy and the process will resume when the channel is sensed idle again for a DIFS interval.

If the last post back-off has already been completed and also if the channel has been idle for a minimum duration of DIFS, an MSDU coming at the station from higher layer has to be transmitted instantly without having to wait for any time.

In 802.11 networks when used CSMA/CA, there can be problem of Hidden Terminal, to solve this problem RTS/CTS (Request to Send and Clear to Send) has been defined. Hence before a station transmits a frame has to transmit RTS frame and receiving station sends corresponding CTS, this RTS/CTS frame includes additional information about how long will the station take to transmit next data frame. So that other stations close to the transmitting station and the hidden terminals near to the receiving station will not be able to start any transmissions as they set their Network Allocation Vector (NAV). SIFS provides a way to transceivers the time to turn around between two consecutive frames in the sequence of RTS/CTS, Data and Ack Frames. The use of RTS/CTS is worth it only when the actual data size is relatively larger than the size of RTS/CTS else there would be much overhead if the RTS/CTS size is comparatively equal to actual data size and the overall performance degrades. Also RTS/CTS can’t be used by broadcast and multicast packets.

DCF provides two types of access mechanisms : Basic Access and RTS/CTS (Request To Send / Clear To Send)., the latter one sends small size RTS/CTS frames before sending the actual data frames, and hence reducing the collisions. Using the RTS/CTS frames it is possible to improve the access control in wireless media and also solve the problem of Hidden Terminal Effect. To initiate the communication the transmitting station sends RTS Signal in response to RTS receiving station sends CTS so that the transmission can begin. Other remaining stations in network, hence update their Network Allocation Vector (NAV).

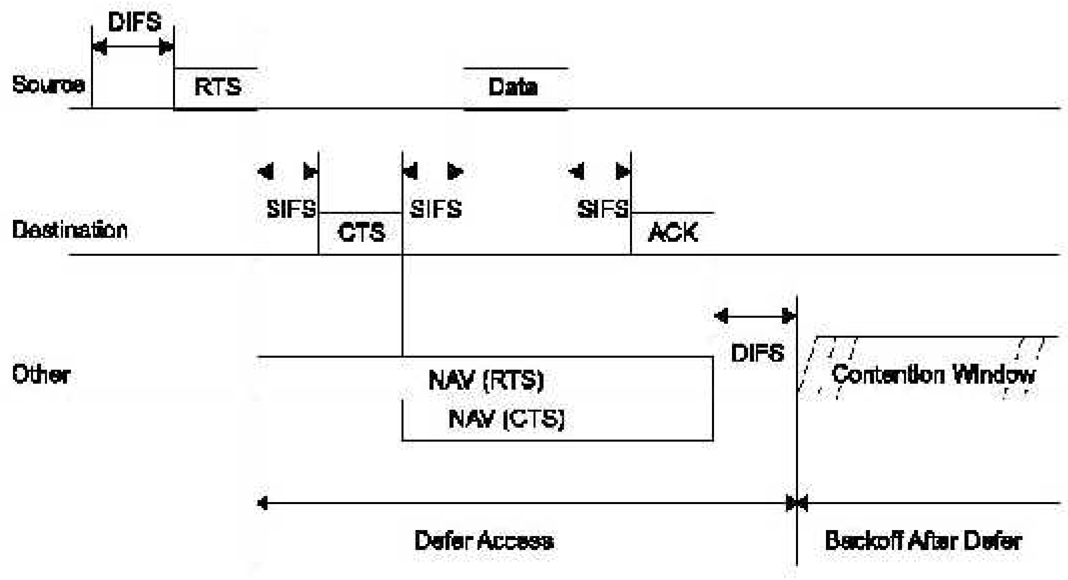

Figure 5: RTS/CTS/data/ACK and NAV setting

2.3 Point Coordination Function (PCF)

In Contrast to DCF, PCF provides contention free medium access method which utilizes polling medium access method with the Point Coordinator (PC) which performs the responsibility of Polling Master. PC resides in AP. PCF is only implemented on wireless infrastructure mode [4]. Generally, PCF has higher priority than that of DCF as PCF may start transmission waiting much shorter time than DIFS. In PCF, the waiting time is termed as PIFS (PCF Interframe Space) which is generally 30ms for 802.11b wireless networks. When the AP gains the control on Wireless Media, it starts polling the associated stations on a polling list. This list consists of all the privileged stations solicited for data frames during the contention free period. During this period, a station is only allowed to make transmission if it gets polled. Using PCF, which interchange a contention free period (CFP) and contention period (CP) over time, which means that when CFP used, PCF is used for media access and when CP used, DCF used for media access mechanism. PCF is used to support time bounded applications although it has some limitations.

In order to support time sensitive services on wireless network, it offers a mechanism to prioritise the access to wireless medium which is controlled by a single point called Point Coordinator (PC) performed usually by Access Point. Also, PCF media access mechanism has higher priority than that access mechanism based on DCF. During CFP, the stations are polled by a central point coordinator (PC) for transmission and they do not try to access medium in their own.

As mentioned above, PCF traffic has higher priority in overlapping BSSs which operates under the DCF access method, (as per the figure 2) PCF may start transmissions after a shorter wait duration than DIFS called PCF Inter Frame Space (Mathematically, PIFS = SIFS + 1 slot time). Hence PCF process creates a free contention period.

During multiplexing PCF and DCF modes are time multiplexed in a super frame which is formed by Contention Free Period (CFP) followed by DCF Contention Period (CP). To provide the management information to the stations AP transmits a so-called Beacon Frame (there are several beacon frames in a super frame). Station uses this beacon frame information in order to associate with an AP, which is performed during the CP and is mandatory when used PCF mode. AP transmits beacon frame periodically, which allows every station to know when the next beacon frame will arrive, this time is called Target Beacon Transition Time (TBTT), this time is announced in every beacon frame, which is required in pre DCF even though there is only contending traffic. Stations will update or set their NAVs at TBTT in every beacon frame during the CFP.

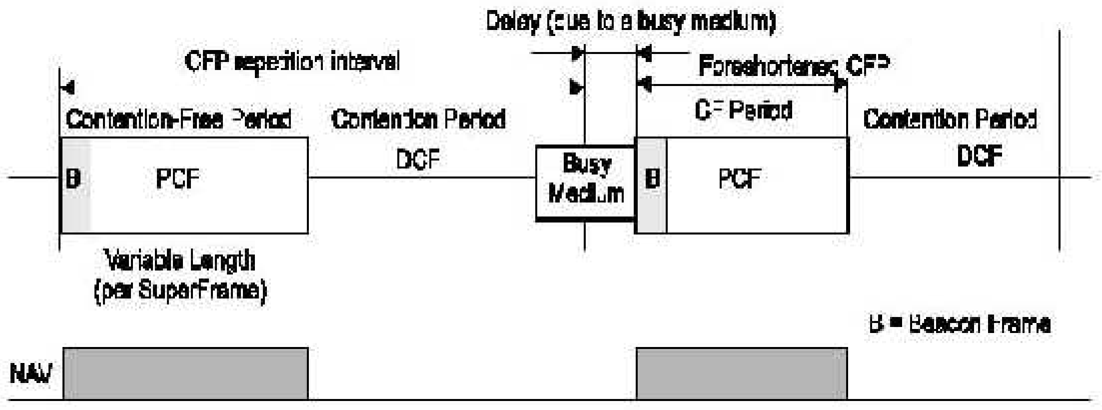

Figure 6: CFP/CP alternation

The polling mechanism used by the PC is a Round Robin Fashion, so only a single station is able to transmit when it gets polled. When a station is polled (the PC can piggyback the CF Poll frame in a data frame and when necessary it is able to piggyback an ACK frame), the polled acknowledges the poll after a SIFS period and may transmit a single MPDU (the polled station may also piggyback the ACK frame), which is a multicast (can be to any destination not just the PC). But if PC does not receive any response from the polled station after waiting for a PIFS, the PC starts polling next station or terminates the CFP using a control frame called CF End.

The minimum CFP is sufficient for the Access Point to send one data frame to poll a station and for the polled station to respond with a single data frame. But in maximum CFP, it must let to send at least one data frame during that period. CFP terminates when the CFP duration has elapsed since the beacon frame which originated the CFP and also may be when the PC sends a CF End Frame.

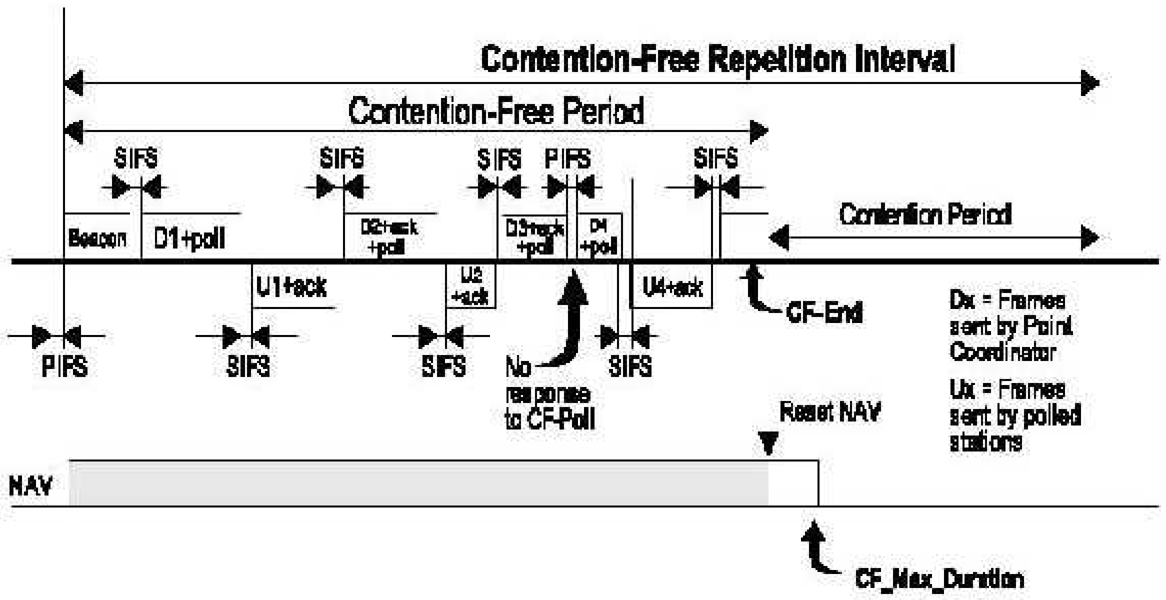

Figure 7: Example of PCF frame transfer

The PCF mechanism does not utilize RTS/CTS mechanism for media access. When the data frames are fragmented, the fragments are sent as individual frames. Some of the limitations with PCF are the unpredictable beacon delays, the transmission durations of the polled stations is unknown and when there is a hidden station which misses the beacon frame.

2.4. QoS Limitation of IEEE 802.11

The major purpose of the MAC layer is to control channel access, maintain QoS and offer security. To sustain QoS support is one of the most demanding functions of MAC layer. In wireless links, it has specific features like high data loss rate, burst of frame loss, packet delay, and delay jitter. As the features of wireless link is invariable and changes according to time and place, it may lead to delay. Whenever users are roaming they expect to receive the same QoS. This means that the new route needs to maintain the same QoS, and the difficulty might occur when the new route could not sustain such requirements.

Normally, QoS is the capability of a network component such as an application, a host or a router to facilitate some level of guarantee for constant network data delivery. There are different ways to characterize QoS in WLAN such as parameterized and prioritized QoS [5]. In parameterized QoS, it follows a strict QoS requirement, in order to acquire the quantitative values for instance, data rate, delay bound and jitter bound. These values are likely to be acquired in the MAC data service in a Traffic Specification (TSPEC) while transferring data frame in peer stations. In prioritized QoS, it is articulated in terms of relative delivery priority, in the MAC data service in a Traffic Specification (TSPEC) while transferring data frame in peer stations. The QoS parameters such as data rate, delay bound, and jitter bound which might change in the transfer of data frames are acquired by the negotiation of TSPEC among Station and the Access Point.

2.5. QoS Limitations for DCF

In DCF, only the best-effort service is offered, as it does not maintain any QoS guarantees. In general, only time bounded application like Voice over IP (VOIP) or video conferencing needs certain amount of bandwidth, low delay and jitter, although it can bear some losses. The basic of DCF is that there is a competition among the STAs for the channel having same priorities. DCF lack the differentiation mechanism to enhance QoS support like guarantee bandwidth, packet delay and jitter.

2.6 QoS Limitations for PCF

Even though, PCF is capable to deal with time bounded multimedia application, three major problems still arise that leads to poor QoS performance [6, 7, 8].

2.6.1. Unpredictable Beacon Delay:

The cooperation between CP and CEP leads to unpredictable beacon delays. The problem is concerned to the uncontrolled length of the CP. The time that it takes to transmit and acknowledge one maximum size frame is the minimum length of CP. As there is lots of traffic competing, the contention service can overrun the end of the CP. As soon as the contention based service runs past the Target Beacon Transmission Time (TBTT), the CFP is foreshortened, and therefore beacon is delayed as shown in Figure 8. Due to this beacon delay, there is delay in the transmission of time bounded MAC Service Data Unit (MSDUs) which is supposed to be delivered in CFP. According to the legacy 802.11 standard, STAs are able to transmit although the MSDU delivery could not terminate before the upcoming TBTT [1]. Due to this, the QoS might be seriously influenced since this leads to unpredictable delay for each contention free period.

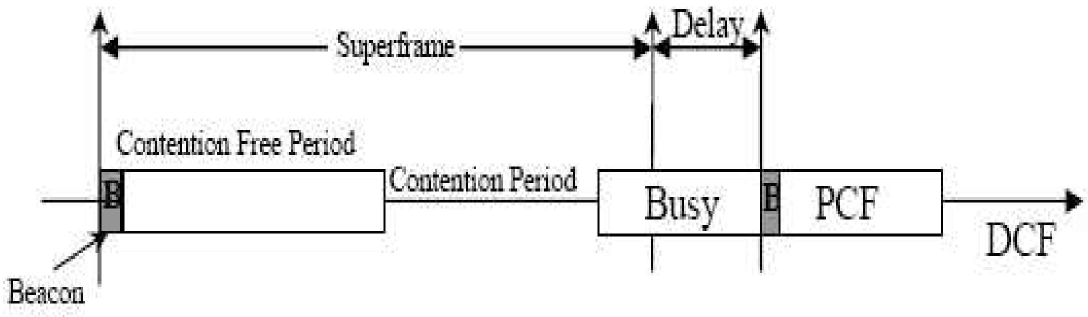

Figure 8: PCF and DCF alternation

2.6.2. Unknown Transmission Time of Polled Stations

The polled stations are only permitted to forward a single frame that is between 0 and 2304 bytes, which is the maximum MSDU size. This might bring in inconsistent transmission time. In addition to this, AP is not capable of foreseeing the transmission time in an exact way because the PHY rate of the polled station can be charged in accordance to the changed behaviour of the channel. Because of this, AP is incapable of providing guaranteed delay and jitter performance to the other STAs in the polling list during the rest of the CFP.

2.6.3. No Knowledge of the Offered Traffic at the Stations

The AP is not aware of the obtainable traffic at the polled STAs with CFP. Every communication among the stations which is in the same BSS goes through the AP. Therefore, too many channel resources are wasted whenever this kind of traffic increases. The STAs are polled by a round-robin scheduling algorithm, lots of time is wasted in polling particular station which have critical time traffic (e.g., CBR traffic). This influences the QoS parameters for those types of traffic categories. For this reason, PCF has no proficient scheduling algorithm that is capable of identifying the different traffic categories at related stations and apply this information to acquire the QoS requirements of various traffic categories. After all, the round robin scheduling algorithm of PCF gives better performance only if each node has something to transmit than only one node does. However, PCF is not capable of providing guarantee for constant real time traffic delivery. For this, new mechanisms are considered to enhance the QoS for IEEE 802.11 wireless networks. In the next chapter, major concepts and methods are described for the MAC improvements for quality of support.

2.7. An Overview of IEEE 802.11e

Since the legacy IEEE802.11 DCF and PCF access mechanisms is not capable of providing enough QoS support for multimedia applications, IEEE 802.11 Task Group E (TGe) [9] was formed for the possible enhancement of 802.11 MAC. In order to provide QoS support, lots of research has been carried out on IEEE 802.11 MAC. Then improved version IEEE 802.11e have been proposed and released. A priority mechanism has been introduced in the enhanced version to facilitate the QoS support that deals with every type of data traffic according to their QoS requirements. Some new features have been added to the MAC layer protocol of 802.11 by TGe (Task Group E), to maintain QoS provision.

In IEEE 802.11e, to reveal the new features of QoS support, some modifications have been made in the acronyms. Such as, STA that works under 802.11e is known as QSTA (QoS Station, i.e., station which support QoS). A BSS (Basic Service Set) in 802.11e is known as QBSS (QoS support BSS).

2.7.1 Provision of QoS

Two types of QoS support are defined in 802.11e for the traffic of a QBSS:

2.7.1.1 Prioritized QoS:

The major concern in the prioritized QoS is the data frame in relation to another. There are eight Traffic Categories (TC) defined in prioritized QoS. In TC, MAC is responsible for handling the set of different data frames with a prioritized QoS. This prioritized QoS is indicated by the Traffic Category Identifier (TCID) and its value’s range is 0-7, inclusive.

2.7.1.2 Parameterized QoS:

Data frames with similar traffic features are put is classes of traffic called Traffic Streams (TS). In parameterized QoS, traffic characteristics means nominal MSDU size, mean data rate, delay bound, etc. This helps in doing the provision of QoS of the traffic streams which are used in QBSS. The parameterized QoS is indicated by Traffic Stream Identifier (TSID) which is unidirectional. The function of TSID is to let the MAC layer know which traffic stream the frames belongs to and what is their QoS requirements. Its value ranges from 8-15, inclusive.

2.8. Hybrid Coordination Function (HCF)

IEEE802.11e introduced the centralized coordination function called HCF, which combines the attributes of distributed medium like DCF and centrally controlled medium like PCF with improved QoS techniques. Basically HCF defines two access mechanisms called EDCA (Enhanced Distributed Channel Access) and HCCA (HCF Controlled Channel Access). EDCF is distributed contention-based channel access mechanism and enhanced DCF. HCCA is centrally controlled contention-free access mechanism. The EDCF is used in the CP only, while the HCF is used in both phases, which makes this new coordination function hybrid.

Three QoS levels are supported in HCF and a certain QoS classification is given in Table 2: Qos Levels in the HCF which illustrates these different QoS levels and their associated scheduling policy.

QoS levels	**Channel access mechanism**	**Scheduling policy**
Level 3	HCF (EDCF and HCF controlled channel access mechanism)	parameterized
Level 2	HCF (EDCF and HCF controlled channel access mechanism)	prioritized
Level 1	HCF (EDCF only)	prioritized
Level 0	DCF, PCF	none

Table 2: Qos Levels in the HCF

QoS Station (QSTA) represents a station which implements both HCF function and QoS facility [9]. HC is defined as a centralized controller in one QBSS (QoS Basic Service Set), that executes the frame exchange sequences and MSDU handling rules defined by the HCF. HC, which is used frequently within the QAP (QoS Access Point), works during both the Contention Free Period (CFP) and the CP (Contention Period). Controlled contention is one of the most fascinating characteristics of HCF for this work. It is a method that reserves short periods of time to request the allocation of transmission opportunities (TXOPs) by sending source request to the HC. In order to begin the frame exchange sequences and to assign TXOP to QSTAs the HC uses point coordination’s higher priority of access to the medium so as to provide Controlled Access Periods (CAPs) to transfer QoS data. During CFP and CP, TXOP might be allocated at suitable times, to meet delay and/or jitter requirements, service rate of particular data traffic flow. The HCF uses virtual carrier sense method (i.e., NAV) in order to protect the transmissions during each CAP that offer better protection of the CFP.

One of the essential characteristics of IEEE 802.11e MAC is the TXOP. It is defined as the interval of time when a specific QSTA begins transmissions in the wireless medium and is denoted by a starting time and maximum duration. At some stage in CP, each TXOP starts either when the medium is available under the EDCF rules (EDCF-TXOP) or when the QSTA receives a special frame form the HC (polled-TXOP). The duration of an EDCF-TXOP is limited by a QBSS-wide TXOP limit distributed in the beacon frames, while the duration of a polled-TXOP is specified in the header of the QoS (+) CF-Poll frame. At some point in CFP, the starting time and maximum duration of every TXOP is specified by the HC using the QoS (+) CF-Poll function. Each QSTA is responsible to make decisions which MPDU can be transmitted within the limits of the period of a TXOP, this way internal collision with one QSTA is avoided. The noticeable point is that in 802.11, PCF is an elective coordination function, but in 802.11e [9] HCF its mandatory coordination function.

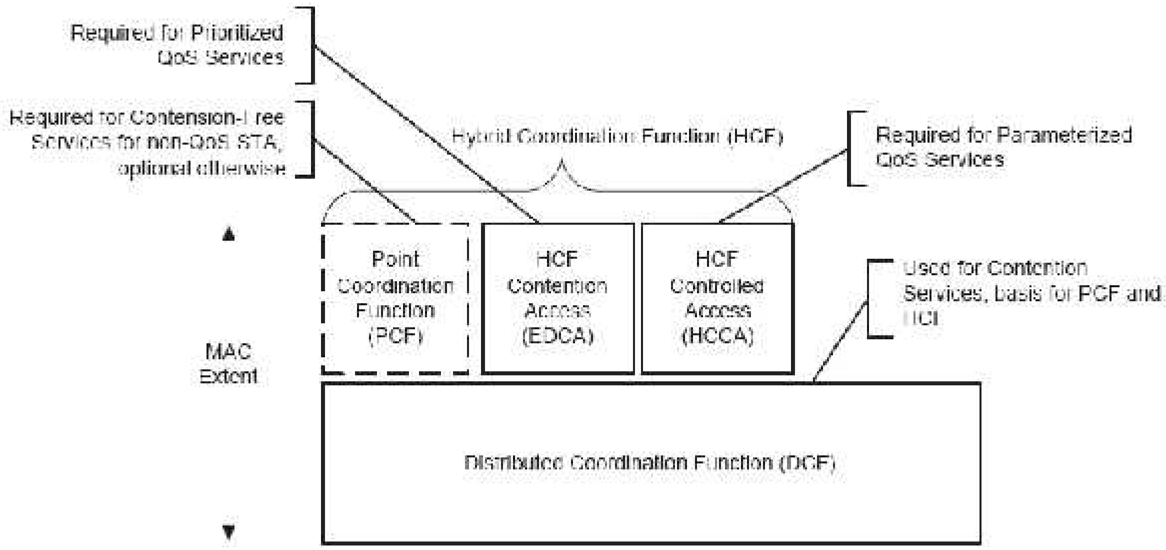

Figure 9: IEEE 802.11e MAC architecture.

2.9 Enhanced Distributed Coordination Function (EDCF)

ECDF is a contention based access scheme [9]. It is an extension of CSMA/CA DCF mechanism to support traffic priorities. The EDCF depicts four Access Categories (ACs) to deal with different kinds of data traffic. These access categories are AC_VO, AC_VI, AC_BE, and AC_BK for Voice, Video, Best Effort and Background respectively. The mappings of frames are according the QoS requirements on their specific AC's where AC_VO and AC_BK have the highest and the lowest priority correspondingly. There is a priority value called User Priority (UP) once a frame reaches the MAC layer, which is mapped to its related AC. The mapping between user priorities and access categories is depicted in Table 3 : User priority to access category mappings.

EDCF QSTAs works similar to DCF in a sense that it listens for the wireless medium to be idle and uses backoff mechanism in order for transmission. But in ECDA approach, when each STA uses maximum back off time, it is different for different ACs. Higher priority ACs has a shorter maximum backoff time than lower priority ACs.

With a shorter maximum backoff time, the higher priority AC gains access to the wireless medium more often than the lower priority AC. Hence, the packet with highest AC gets access to the medium more often than those of the lower AC. But if the packets are within the same AC with the same maximum backoff time, contend in fair manner with one another inside that AC so as to access to the wireless medium.

Priority	User Priority	802.1D Designation	Access Category	Designation
lowest	1	BK	AC_BK	Background
	2	-	AC_BK	Background
	0	BE	AC_BE	Best Effort
	3	EE	AC_BE	Video
	4	CL	AC_VI	Video
	5	VI	AC_VI	Video
	6	VO	AC VO	Voice
highest	7	NC	AC_VO	Voice

Table 3 : User priority to access category mappings.

EDCF provides differentiated service in which the bandwidth offered is dispersed which depend upon the Traffic Categories (TC), and each TC has different priority. The Table 3 : User priority to access category mappings., shows the different Access Categories, i.e., 8 queues at MAC layer to support 8 Traffic Categories (TCs). Different from a station, a QAP should support at least 4 ACs. Priority is provisioned by the configuration of the time to access the channel once it is sensed idle and by changing the size of the contention window. Contention window is used to allocate priority to each TC. In fact, in most of the case, when a short contention window is assigned to a high priority TC, it is capable of transmitting ahead of the low priority one. Therefore, for various TCs, different CWmin and CWmax parameters can be set differently.

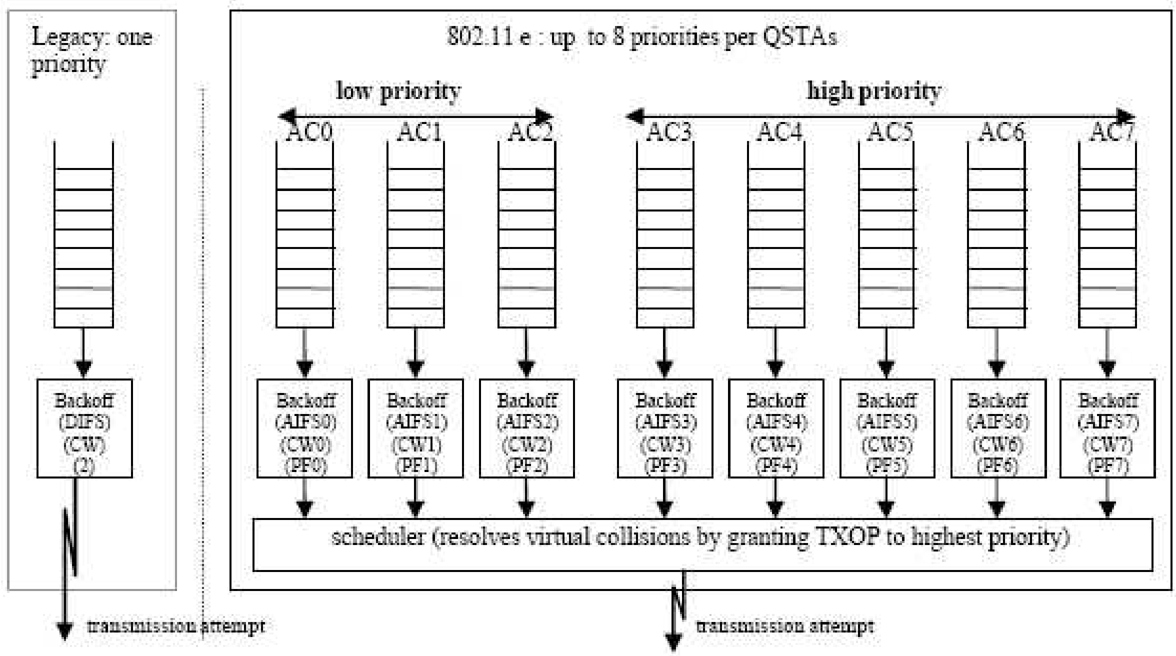

Figure 10: 802.11 EDCF vs Legacy DCF

In EDCF, every STA must be able to provide between four to eight TCs, with their independent transmission queues. Once the device has accessed the wireless medium, it has chance to continue transmitting for a particular transmission opportunity (TXOP), which is other enhancement of EDCF over DCF. Every Traffic Category (TC) within the station competes for a TXOP and separately begins a backoff procedure once it detects the channel for an Arbitration Interframe Space (AIFS). AIFS is chosen separately for each TC which is at least DIFS. Each backoff locates a counter to a random number of intervals [1, CW+1]. Other parameters which depend on TC are CWmin and CWmax.

Similar to DCF, AFIS have to wait for the medium to be idle, when it is busy before the counter reaches zero. The difference is that when the medium is idle again for AFIS, the backoff counter is reduced by one. Whenever there is any unsuccessful transmission, a new CW is calculated using the persistence factor (PF). PF is dependent on TC and find out the degree of increase of the CW when collision occurs. The new CW can be calculated using following equation:

CWnew[TC] = ((CWold[TC]+1) * PF) – 1

The highest probable value for the contention window associated with the TC is CWmax [TC] and CW never exceeds this parameter.

In order to avoid collision, whenever two or more parallel TCs backoff counter reaches to zero in the same station, it uses TXOP to the higher TC or AC, as shown in figure 9. In the mean time, the lowest priority TCs act as if there is an external collision on the wireless medium. Though, whenever this type of collision occurs, there is no retry counters related to MPDU involved in collision. As, EDCF is only capable of dealing with the possibility of internal collisions, there might be chances of external collisions at the wireless medium while transmission of frames by other stations.

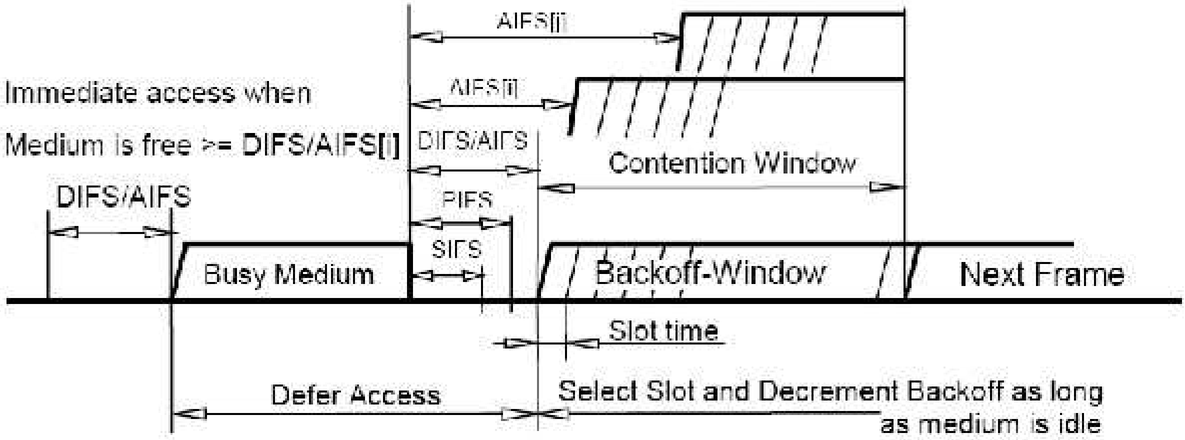

Figure 11: Some IFS Relationships

For the enhancement of IEEE 802.11e, packet bursting such as EDCF bursting and Contention Free Burst (CFB) can be used. This could help to enhance performance and achieve better medium utilization. In fact, once the station has got access to the medium, it is allowed to transmit more than one frame without competing for the medium. It can also send as many frames it wishes as long as the total access time does not surpass the certain limit, e.g., TXOPLimit. A shorter IFS (SIFS) is used between frames to make sure that no other station interrupts the frame bursting. And the packet bursting is terminated if there is any collision. As a result, network overhead is reduced and throughput is increased by the use of EDCF bursting. The multiple transmissions using SFIS and bursting acknowledgement support has better fairness in Traffic Categories (TCs) of same priority. On the other hand, EDCF bursting might increase the delay jitter, so in order to avoid that TXOPLimit must not be longer than the time required transferring the largest data frame. Frame bursting is also used in HCF Controlled Channel Access mode like in EDCF, which is discussed in next section.

2.10 HCCA (HCF Controlled Channel Access)

The purpose of HCCA is to improve efficiency by decreasing the contention on the medium. HCCA mechanism makes use of Hybrid Coordinator (HC) to centrally deal with medium access. The HC is frequently used with the QoS enhanced access point (QAP) of a QoS Basic Service Set (QBSS). It has the utmost priority to access the wireless medium, start the frame exchange sequence, and to assign TXOPs to the wireless Stations (WSTAs). To achieve the QoS requirements of the specific TC, HC traffic delivery and TXOP allocation might be scheduled in both CP and CEP. The information about the contention free traffic from HC is dependent on the HC's QBSS-information about the traffic pending in TCs. Collisions is unlikely to take place apart from the stations on the same frequency that are not under control of HC.

In HCF controlled channel access mechanism, short bursts of frames are transmitted using polling -based controlled access mechanism in which CAPs are defined as a number of intervals in one CP. However, EDCF contention based rules are used to transfer the remaining part of the CP frames. The figure 11 depicts the correlation between CFP, CP and CAPs in one 802.11e superframe [10].

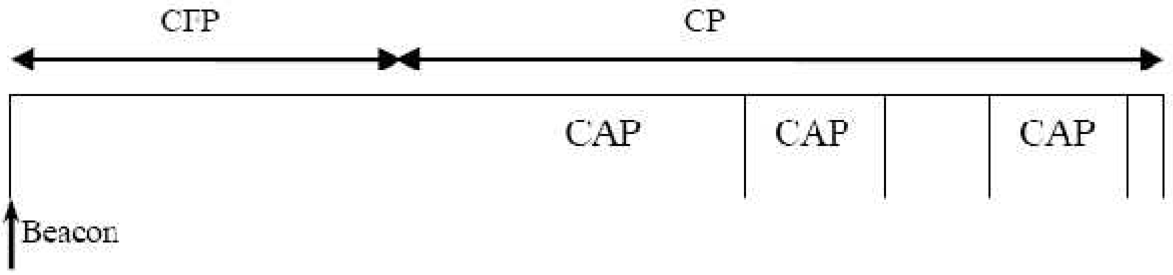

Figure 12: Relationship of CFP, CP, and CAP within one superframe

Whenever QSTAs request any new TXOPs, contention might take place. In such case CAPs needs to include Controlled Contention Intervals (CCIs). In order to provide integrated Service (IntServ) such as guaranteed services [11] like bandwidth, delay, jitter, loss or error rate requirements, pure EDCF is unable to provide completely. For this, HCF can offer guaranteed service when Controlled Contention (CC) is used in CAP. The probability of getting guaranteed service is higher than pure EDCF in this way, especially when there is heavy traffic load. HCCF mechanism offers effective policing and channel access by controlling the channel.

When HC forwards a particular Controlled Contention (CC) frame, the Controlled Contention Interval (CCI) is started in which each instance of CC occurs. The function of the CC control frame is to improve and protect the CCI duration by compelling the stations to set their NAVs till the end of CCI. HC includes a priority mask, the duration of each Controlled Contention Opportunity (CCOP), and the number of CCOPs within the CCI (NCCOP) which is generated by CC frame. In the priority mask, which is also known as filtering mask, contains the TC in which Reservation Requests (RR) might be placed. The figure 13 below depicts the CCI, CC frame as well as RR placed in each Controlled Contention Opportunity (CCOP).

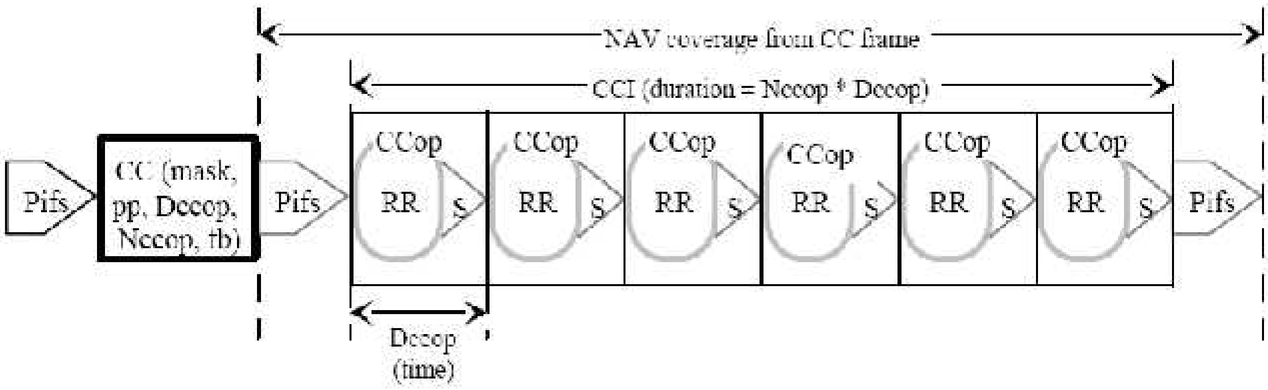

Figure 13: Controlled contention interval and different IFS (CC/RR frames)

Every QSTA have Reservation Request (RR) which is sent for a TC to match the priority mask. Each QSTA, when control frame CC is received, choose a particular CCOP by using random access protocol like CSMA/CA to send its RR. This is done only after it enters a particular backoff time parameterized by NCCOP and DCCOP. Because random access protocol is used in RR transmission, there might be chances of collision of RR frames; in this case there is not any retransmission procedure. If the frames are transmitted successfully, the acknowledgement is received by HC to various QSTAs in the next CCI sequence by the help of feedback field (fb), as revealed in the figure 12 in the CC frame. Due to this mechanism, there is a fast method of collision declaration; as a result, the collision can be detected during the next CCI by the requesting QSTAs. Figure 14 demonstrates an instance of 802.11e superframe (which is also called beacon interval).

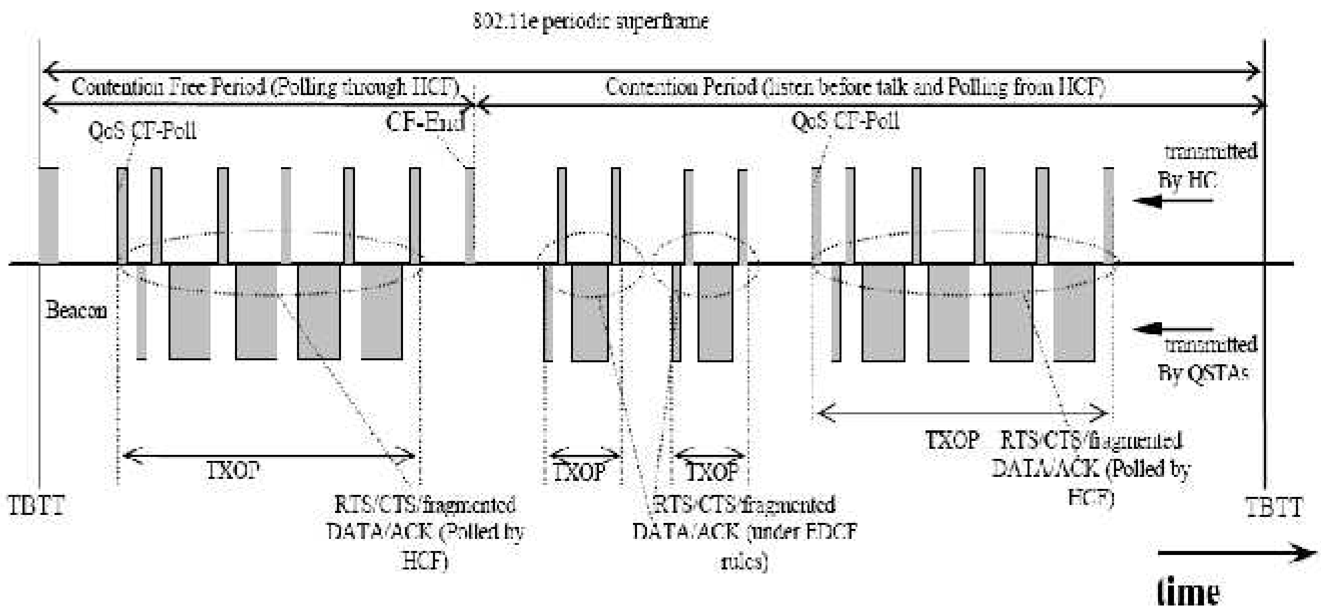

Figure 14: A typical 802.11e HCF superframe (both CFP and CP)

Contention free Period (CFP) and Contention Period (CP) are the two phases of superframe. In CFP, the initial time and the highest duration of each TXOP is specified by the HC by the use of CF-Poll frames. By the help of HC only TXOP can have access to the wireless medium. QSTAs cannot and will not try to get the access on its own. It is the HC which can grant the TXOP to these STAs. When the time is announced in the beacon frame, CFEnd, from the HC, the CFP finishes. In CP, there are two ways each TXOP starts. Either the medium should be available under EDCF rules, i.e., after AIFS plus backoff time, or after QSTA receives the QoS CF-Poll from the HC. The HC, using its high priority medium access can issue TXOPs in the CP.

A Contention Free Burst (CFB) might take place for the achievement of the better medium utilization in the CFP. CFP allocate a series of MPDUs to be transmitted which is separated by a SIFS period for the transmission. For the acknowledgement of MPDU within the burst is done by BurstAck MPDU, which is requested by a BurstAck, originally requested from WSTAs. Due to this request/response mechanism, the recipient gets time to perform any necessary Forward Error Correction (FEC) decoding.

When the burst receives QoS CF-Poll frame from HC, it is initiated and it is not necessary to have Traffic Specification (TSPEC) which can be applied to both FEC and non-FEC use. In a single TXOP, the duration values of burst data MPDUs and any ACK exchange should fit. The most important function of CFB is that to enable the HC to hand over medium control (probably to other QBSS) and postpone the control until new frames of other CFB are available. In this way, it helps to solve the problem of overlapping of BSS and give the medium control to other QBSSs in the similar area [12].

2.11. Enhanced Distributed Channel Access Function (EDCAF)

EDCAF is an enhanced version of DCF that competes for the wireless medium access based on the specific parameters ohf an AC. Two EDCAF parameters, Arbitration Inter Frame Space (AIFS) and CWmin and CWmax are described below [13].

2.11.1 Arbitration Inter Frame Space (AIFS)

AIFS is the least time interval in which the wireless medium is found idle ahead of transmitting the frames. To derive AIFS, below is the mathematical equation:

AIFS=AIFSN x aSlotTime + aSIFSTime

Where,

AIFSN (Arbitration Inter Frame Space Number) denotes the length of AIFS,

SlotTime denotes the slot time, and

SIFSTime denotes the SIFS time period

Due to the smaller AIFS values, ACs with high priority needs to wait for less time before transmitting. On the other hand, if ACs has low priority, they needs to wait for longer time and might bear from long delays due to their high AIFS values.

2.11.2 CWmin and CWmax

The minimum and the maximum contention window size differ among ACs. CWmin and CWmax values are greater in low priority ACs and vice versa. Hence, in the small contention window AC, the EDCAF associated with specific AC picks up a small random backoff value. Like this, when the medium is idle, EDCAF have to wait for very short AIFS time period. When the CWmin is of small size, there is possibility of increasing the amount of collision with high priority ACs

ACs	CWmin	CWmax	AIFSN
AC_BK	31	1023	7
AC_BE	31	1023	3
AC_VI	15	31	2
AC_VO	7	15	2

Table 4: EDCA Parameter Values

2.12. Performance of 802.11e

Several simulations have been done for the evaluation of EDCF and HCF under different load conditions in context of related work [7]. EDCF scheme is capable to support enhanced QoS than DCF and PCF in the low medium load conditions, which can be revealed through performance analysis [12]. On the other hand, when the medium load increases EDCF based network is saturated and throughput is reduced. As the parameters in the EDCF are static and it is not adapted to the rate of traffic load, it becomes complicated to locate the optimal EDCF parameters which can provide the best performance. For this HCF Controlled Channel Access is the better option. As in HCCA there is QoS-aware scheme for different queues in each QSTA which can give better performance than EDCF. But due to the lack of admission control policy for HCF, it is good for only certain traffic load and it does not work well when the load exceeds the QoS-load upbound.

2.13. Open Issues

There are still lots of open issues regarding the proposed QoS mechanism for IEEE 802.11e standard [12] and many research works are in progress to increase its performance. In fact, this is still unstable and therefore need more exploration and testing. Some of the issues are as follows:

- **Optimal EDCF**: As the parameters in the EDCF are static and is not adapted to the rate of traffic load, it becomes complicated to locate the optimal EDCF parameters which can provide the best performance. So there is decreased performance in high load environment. And the research is still ongoing to adapt the parameters to the traffic load.

- **The problem of interference between QBSSs**: the robustness of the polling scheme under HCF in comparison to EDCF when there is any interference is still not studied, which can be either from station, from a hidden node or from other AP.

- **The problem of admission control policy in HCF i.e. validation:** there is no admission control policy in HCF such as for guaranteed service, scheduling algorithms. For this reason, HCF needs an admission control policy and in order to provide trade-off between channel efficiency, priority and fairness.

- Adequate support between MAC level Forward Error Correction (FEC) and other higher layers error control protocols.

- Evaluation of the performance and effectiveness of EDCF packet bursting and contention-free burst (CFB).

2.14. Evaluation of Work Related to QoS

From the time when the first IEEE 802.11 standard was published in 1997, there have been quite few works researched and published in order to offer performance analysis and enhancement. Earlier, most of the works aimed to improve the channel utilization by analysing the channel performance in both single traffic class and the backoff mechanism. Afterwards, with the fame of WLANs, there has been lots of research in order to provide QoS differentiation or guarantee in WLAN. Although various research efforts have been made for the QoS enhancement and modelling of 802.11 DCF, some of the researcher's works that deals with multiple class traffic are discussed below.

Choi *et al.* [14] evaluated through simulation that EDCF is able to offer differentiated channel access by comparing the 802.11 DCF and 802.11e EDCF. For the better performance and the medium utilization, Contention Free Bursting (CFB) which is used in EDCF is also examined through simulation. A shorter IFS (SIFS) is used between frames to make sure that no other station interrupts the frame bursting. Multiple MAC Protocol Data Units (MPDUs) are transmitted by the help of CFB within the time bound of the TXOP limit. It is revealed that the CFB improves the system performance and enhance the QoS support.

Lindgren *et al.* [15] evaluated through simulations four mechanisms to offer service differentiation in IEEE 802.11 wireless LANs: the Point Coordination Function (PCF), the Enhanced Distributed Coordination Function (EDCF), the Distributed Fair Scheduling (DFS) in [16], and the Blaskburst scheme in [17]. From the simulation, it is revealed that all the mechanisms are capable of offering service differentiation to some extent but their performance is decreased when there is large number of high priority stations. For thisConncetion admission control is very crucial option. The performance of Blackburst and EDCF are also not better if there are high loads of high priority traffic. Hence, as much as relative differentiation is concerned, DFS is most possibly the best mechanism.

Pong and Moors [18] evaluate through simulation that the performance of EDCA is able to enhance QoS support for the wide range of multimedia applications. By the help of simulations, they revealed that by proper selection of TXOP, CW, and EDCA is capable of providing better QoS support than the existing DCF mechanism.

Xiao [19] analysed the work dealing with the multi class traffic. He expanded the Markov chain model in [20] included three adaptable parameters (the initial contention window size, the retry limit, and the back off window-increasing factor) and multiple priority classes into the model. From this model the working effectiveness of IEEE 802.11e related to throughput, delay and dropping probability can be logically derived. But the tuneable parameter in IEEE 802.11e, AIFS, is not modelled. Furthermore, to meet the QoS requirements by fine- tuning the above parameters of various traffic classes is not argued.

CHAPTER 3: METHODOLOGY

In this project simulation techniques were preformed using OPNET Modeler 14.5. Simulations were performed with a scenario with voice stations, video stations and data stations for both DCF and the EDCF. Comparisons were made in the aggregated throughput of each traffic type stations. Rate of delay in frames were observed, for voice, video and data for DCF and EDCF. Interpretation and analysis were done based on the output each simulation scenario.

3.1 Solutions for QoS in WLAN

Even though, there are lots of related QoS systems in each layer of networks, but as in this project, only the four parameters Throughput or bandwidth, Delay or latency, Delay jitter, Loss or error rate, are discussed. QoS guarantee in WLAN can be divided into four blocks as follows:

- Differentiation serving system,
- Information extracting system based on physical layer,
- Resource reserving and connection admission control (CAC) in MAC layer,
- IEEE 802.11 parameters tuning system

3.1.1 Differentiation Serving System

In Differentiation serving system, different service levels are allocated to different groups of users. It means that different applications are classified into different classes and should be served individually with different QoS parameters. There are two methods of differentiation service in IEEE 802.11: Priority based service and fair scheduling service.

3.1.1.1 Priority based service

In Priority based service, the highest priority data are served first than those of the medium or lower priority data. For this, there is a classification mechanism which identifies and separates the traffic into different flow and handle individually. In fair scheduling service, the bandwidth is fairly scheduled which depends upon the weight of each type of traffic, in order to avoid giving the service to the lower priority flows every time.

3.1.1.2 Distributed Fair Scheduling (DFS)

Vaidya et al. [21] suggests an idea called Distributed Fair Scheduling (DFS), which is an access method for fair queuing in wireless medium. With the help of backoff mechanism of IEEE 802.11, DFS decide that which STA should transmit first or given the most priority. The differentiation is accomplished by the backoff interval. If the backoff interval is longer, the weight of the sending station is lower. But, the fairness of the traffic is accomplished by making the interval proportional to the packet size.

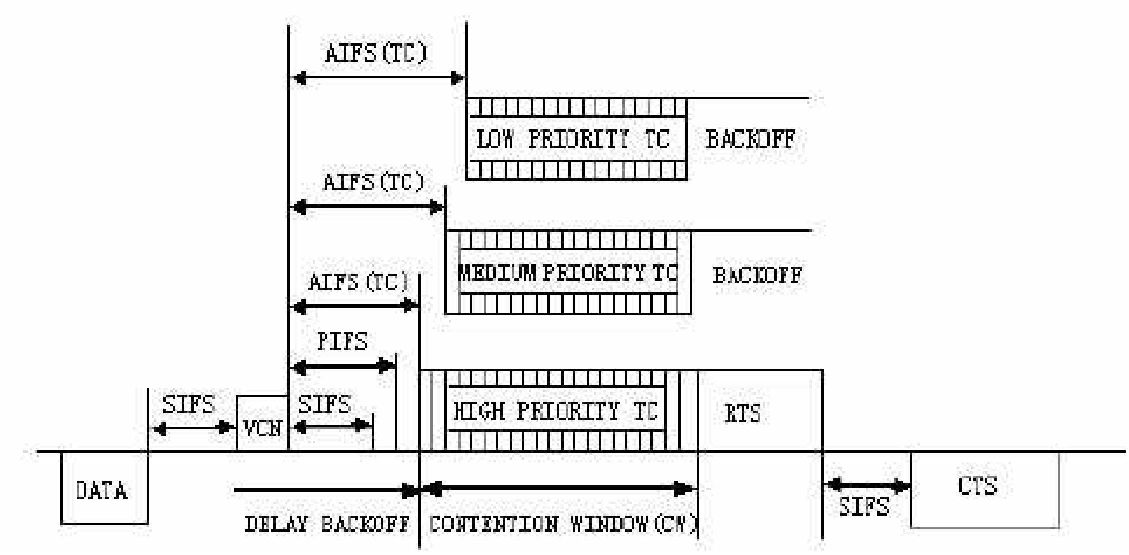

Figure 15: EDCF of IEEE 802.11e

For instance, as shown in the figure 15, there are eight different classes of TC in each station as defined in IEEE 802.11e. The priority of QoS guarantee parameters is allocated differently in each class. In addition to this, to access the channel every station with different priority needs to wait for different AIFS time and then each station's counter sets a random number from [0, CW+ 1], and starts to backoff. In this case, CWmin depends on TC. Moreover, whenever any collision occurs, due to IEEE 802.11e CW adjusting system, the usual DCF doubles CW simply, whilst the EDCF alters the previous CW based on persistent factor (PF).

3.2 Information Extracting System Based on Physical (PHY) Layer

In order to enhance QoS support, it cannot be dependent only in the MAC layer. It is essential to have close interaction between different layers of network system i.e., from application layer (e.g., the coding scheme selected) down to physical layer (e.g., the channel transmission rate selected). It is very important to get the information regarding transmission situation regularly from PHY layer, for some parameters of MAC layer to be adjusted for the achievement of maximum throughput and minimum delay.

In order to utilize the information acquired from physical layer, the distinction between the Measured Value Parameters (like BER, SNR, etc) and those with the values defined by the standards related to the concerned physical layer (like aSlotTime, aCWmax, aCWmin,DIFS, SIFS, PIFS etc) [21] are done.

One of the most important parameter of the Physical Layer is Signal to Noise Ratio (SNR). SNR concerns the useful rate which has dependency on data packet computing. Using Bit Error Rate (BER), only the state of the medium and the Quality can be calculated but BER is only calculated at the receiving station. The transmitting station is considered "blind" because BER entity only has meaning associated with the receiving station. Mathematically it can be interpreted SNR as:

$$\text{SNR} = \frac{\text{Emitted/received signal power}}{\text{Noise power}}$$

The SNR value indicates MAC about the kind of traffic to be sent according to the medium quality. The below limits are defined:

$(SNR)_{BE}$ is the acceptable limit of SNR for the “Best Effort” traffic,

$(SNR)_{QoS}$ is the acceptable limit of SNR for the “QoS” traffic.

The below condition have to be observed

If $(SNR) < (SNR)_{BE}$, The station differs emission

If $(SNR)_{BE} \leq (S/N) < (SNR)_{QoS}$, Then the station differs emission if it has QoS traffic, Else, it emits the Best Effort traffic

If $(SNR) \geq (SNR)_{QoS}$, Then, station transmits in both cases of Best effort or QoS traffic.

It can be noted that the benefit of interaction between layers and the narrow dependence between decision to emit or change the emission on the Media Access Control level. And also the SNR on the physical level and traffic classes on the Network level.

Since, IEEE 802.11 maintains to acquire SNR parameter from PHY layer, it is best to make use of SNR of the channel. In [21], in order to make entire WLAN capable, it is presumed that RSS (Reserved Signal Strength) and SNR have linear relationship, every station is allocated with various RSS threshold for the use of different transmission rate.

For the estimation of the condition of the wireless channel, the base of the algorithm is the combination of SNR parameters, payload length and transmission counters in [22]. To decide the quality of the wireless channel, the same algorithm can be used to make sure the number of times it succeeds of fails to send constantly. Normally, if the transmission rate is bad, station must decrease the transmission rate.

In order to estimate the quality of wireless channel from SNR, each station transfer its SNR information to AP by SNR frames regularly in [23]. On the basis of this information, the SNR table is kept up to date by AP, which is sustained by AP itself. So as to maximize the throughput of WLAN, the table sustains couple of station (STA) ID with its SNR, and organizes bandwidth for each STA.

3.2.1Resource Reserving and Connection Admission Control (CAC) in MAC Layer

To facilitate high QoS guarantee in real time multimedia applications, service classification is very essential. However, when there is lots of traffic, it does not work well due to heavy loading. Therefore, it is important to reserve resource and control accessing in MAC to guarantee the QoS of that type of application.

3.2.1.1 Resource Reserving

In IEEE 802.11 WLAN, resource reservation is normally used in centralized protocols. Based upon the availability and demand, the resources are allocated in accordance to the priority of the classes which is categorised based on the application by distributed protocols. Fairly, traffic with higher priority class is given more resources than those of lower priority. It is tough to maintain resource reserving in 802.11 WLAN based on CSMA/CA. For that, it needs some modifications to reserve the resource. For instance [24], describes that by means of multi-channel accessing in MAC layer can maintain resource reserving.

3.2.1.2 Connection Admission Control (CAC)

Connection Admission Control (CAC) is an entity located at the AP and is based in the standard procedure defined in [25]. CAC is implemented in the AP which operates in infrastructure mode. The major task of CAC is to monitor collision, throughput estimation and to make admission decision. In order to keep track of collision rate, every active flow needs a counter. CAC must decide whether to accept the connection or not, provide parameters required and perform routing and reserve allocation.

Due to the wireless environment, it is difficult for Access point or Station to identify the accurate condition of the current loading. So, it is hard to make decision which type of access controlling. For this, there are two basic mechanisms, first is to choose the current network situation, and the second is to conclude the network situation based on the calculation.

There is some suggestion to verify channels inactively by virtual frame in MAC in [26]. Estimating the current service level virtual frame and correct the appropriate parameters dynamically based on the modification of the channels condition through virtual MAC and virtual source algorithm. In [27], with the support of the calculation, the condition of the networks station is estimated and made access control consideration.

As simulation of Lindgren *et al:* [15], shows that their performance is decreased in order to offer service differentiation when there are large number of high priority stations. So, there is a need of CAC, which is a very crucial option.

CHAPTER 4: RESULT AND ANALYSIS

This chapter presents the simulation obtained of the two approaches and evaluates the two approaches based on the relevant papers are presented in this thesis report.

4.1 Tuning IEEE 802.11 Parameters

Tuning parameters has a major impact in order to enhance the performance of WLAN. In [28]: Table 17-1. “Summary of common tuneable parameters", list out these parameters. Like in Xiao [19], there is a need to tuneable parameter in IEEE 802.11e, it helps to enhance the performance.The parameter RTS_Threshold is normally cited in the research as in **Error! Reference source not found.**. RTS_CTS system is particularly proficient if long MSDU packets transmission is needed which is based on the conclusion in [29]. It is suggested by author, that it is better to set RTS_Threshold as 0 which is using RTS_CTS system every time than to calculate the number of active stations in order to adjust RTS_threshold dynamically.

parameters	Meaning and unit	Effect when decreased	Effect when increased
RTS Threshold	Frames larger than the threshold are preceded by RTS/CTS exchange.	Greater effective throughput if there are a large number of hidden node situations	Maximum theoretical throughput is increased, but an improvement will be realized only if there is no interference
Fragmentation Threshold	Frames larger than the threshold are transmitted using the fragmentation procedure.	Interference corrupts only fragments, not whole frames, so effective throughput may increase.	Increases throughput in noise-free areas by reducing fragmentation acknowledgment overhead.

Table 5: Parameters of RTS threshold and fragmentation threshold

Moreover, another admirable parameter for further study is Fragmentation_Threshold. In poor wireless environment, to achieve more throughputs, it is better to control RTS_Threshold dynamically which depends on the channel quality feedback from lower layer. To enhance WLAN's throughput and data rate, dynamical tuning Long Retry Limit and Short Retry Limit. Once RTS_Fragmentation is invoked and perform some testing to decide the number of collision is reduced than the resulting throughput is improved.

4.2 Simulations Result and Analysis

Simulations parameter:

EDCF PARAMETERS USED FOR SIMULATIONS

Type	Prior.	AC	AIFSD	CWmin	CWmax	TXOP limit (msec)
Voice	7	3	PIFS	7	15	3
Video	5	2	PIFS	15	31	5
Data	0	0	DIFS	31	1023	0

Table 6: EDCF Parameters for Simulations

In this scenario, it is simulated with four voice stations, two video stations, and four data stations for both the DCF and the EDCF. Fig.16 shows throughput, delay, and data dropping rate for the DCF and the EDCF. By comparing Figs. 17 and 18, which plot the aggregated throughput of each traffic type, it is observed that the throughputs of video and data are significantly different for the DCF and the EDCF. Knowing that the aggregate video rate from two stations is 2.8 Mbps, it can be easily imagined that the video traffic is well served with the EDCF while many video frames are dropped with the DCF. This fact is confirmed in Figs. 17 and 18, which show significant reduction in video frame losses with the EDCF.

Note that a frame drop occurs when there is a buffer overflow. There is small voice frame loss with the DCF while there is none with the EDCF. On the other hand, it is observed that with both the DCF and the EDCF, there is no data frame drop as an infinite size buffer is used for data stations. Instead, data frame delay goes to infinity with both the DCF and the EDCF.

Note that the delay for data is not plotted in Fig. 16 so as to clearly show the delay performances for voice and video with the EDCF. It is observed in Fig. 16 that voice performance is significantly improved via the EDCF. Note that with the DCF, the voice frame delay sometimes goes over 250 msec, which is not acceptable in most cases. The video delay performance is also improved remarkably with the EDCF. It should be noted that each delay curve is from a single station, e.g., one of four voice stations while the previous throughput and data dropping rate were aggregated from all the same types of stations. That is the main reason why the peaks in data dropping rate and delay curves look totally uncorrelated. One interesting observation is that even with the DCF, the voice frame delay is much smaller than those of video and data frames. That is because virtually every voice frame arrives at an empty queue thanks to its traffic pattern. That is, each voice frame is transmitted after contention before the next frame arrives at the queue. Note that a voice frame arrives at a transmitting MAC every 20 msec while the voice delay with the DCF is less than 20 msec in most cases. From the results thus far, it is concluded that the EDCF can provide differentiated channel accesses for different traffic types. With the observed delay and error performance, it is expected that the EDCF can support real-time applications with voice and video traffic with a reasonable quality of service in certain environments.

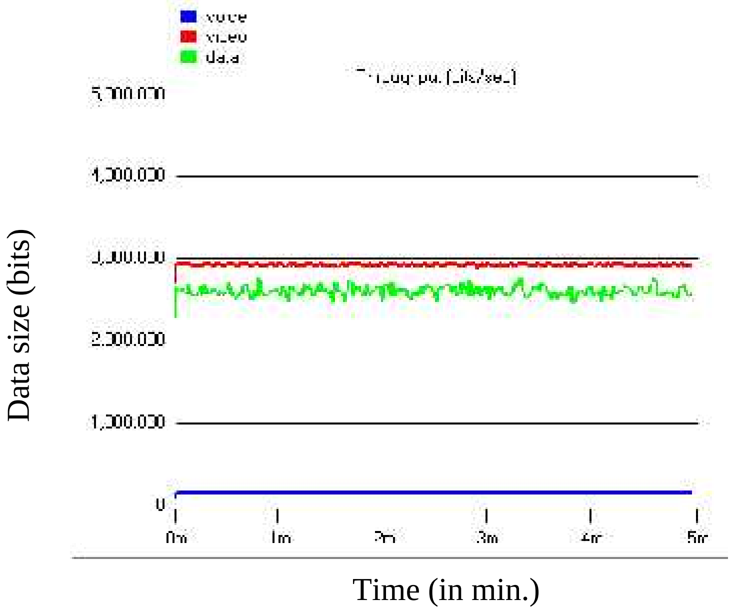

Figure 16: Throughput (bps) with EDCF

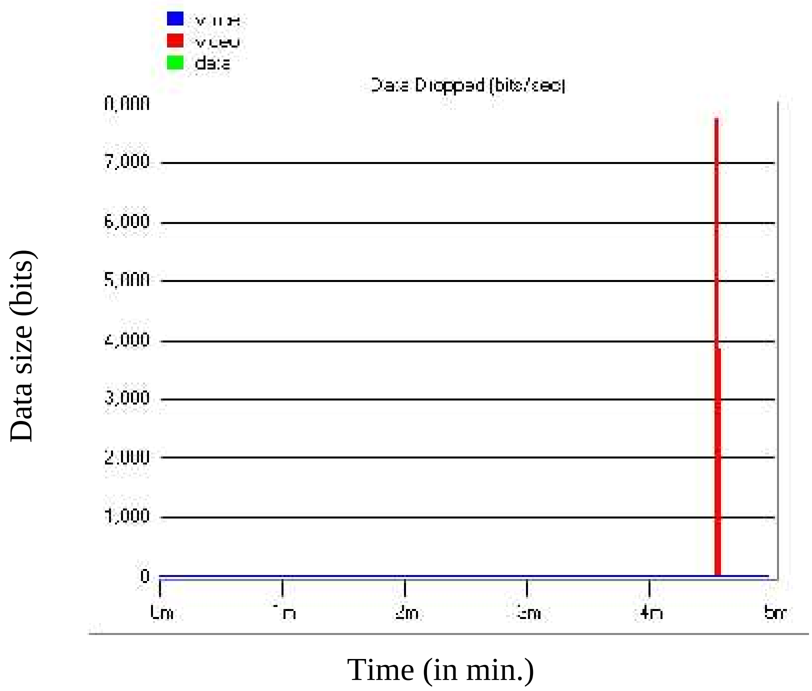

Figure 17: Data dropped (bps) with EDCF

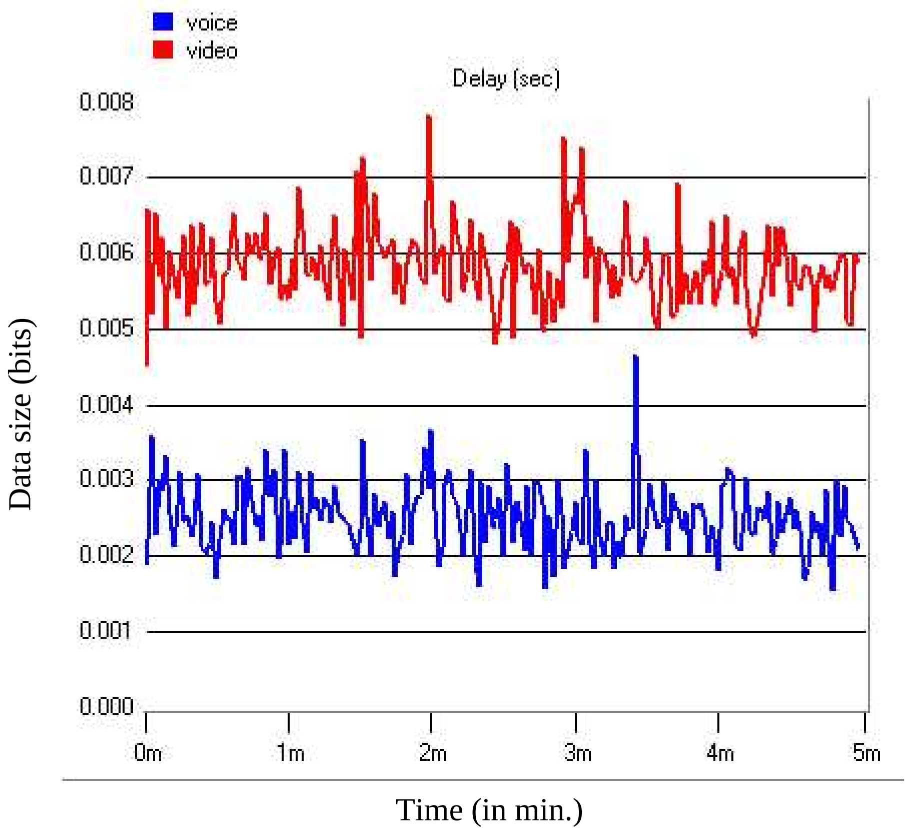

Figure 18: Delay (sec) with EDCF

It is now also observed from Fig. 17 that the video delay performance is significantly improved with CFB as the video stations enjoy reduced overheads for backoff. With CFB, video delay stays regularly below 400 msec, which should be an acceptable value for most video decoders. Finally, Fig. 18 shows that the voice delay performance is degraded with CFB due to the statistically extended transmission times of video stations. However, it is also observed that the voice delay stays within 8 msec most of the time, which is acceptable for even the most interactive voice applications.

CHAPTER 5: CONCLUSION

In this project work, the first chapter, familiarizes IEEE 802.11 protocols and evaluates QoS limitations in the second chapter. In wireless medium, legacy DCF and PCF access mechanism is only capable of providing the best effort service. In this project work, evaluation and analysis of QoS techniques and enhancements of MAC layer protocol is performed. By assigning high priority to particular station, the major QoS techniques boost the DCF access mechanism to offer differentiated services. The QoS requirements depend from application to application. In this project, four important classes of QoS guarantees which can be used in WLAN are suggested. These are differentiation serving system, information extracting system based on PHY layer, resource reserving and CAC in MAC layer and IEEE 802.11 parameters tuning system. Different applications which are classified into different classes should be served individually with different QoS parameters. It is very much essential to acquire information from PHY layer for some parameters of MAC layer so as to achieve maximum throughput and minimum delay. The resources are allocated according to the priority of the classes. Most of the schemes so far focus on throughput guarantees. For the other QoS metrics, such as delay and jitter the CAC and resource allocation is a better research area. Simulations were performed with a scenario with voice stations, video stations and data stations for both DCF and the EDCF. Comparisons were made in the aggregated throughput of each traffic type stations. Rate of delay in frames were observed, for voice, video and data for DCF and EDCF. Interpretation and analysis were done based on the output each simulation scenario. It is observed that throughputs of video and data are significantly different for the DCF and the EDCF. Video traffic were observed to be well served with the EDCF while many video frames are dropped with the DCF. It was also observed that voice performance and video delay performance is significantly improved via the EDCF. One interesting observation is that even with the DCF, the voice frame delay is much smaller than those of video and data frames. With the observed delay and error performance, it is expected that the EDCF can support real-time applications with voice and video traffic with a reasonable quality of service in certain environments.

Lots of researches have been carried out and still are being done in order to enhance QoS performance in WLAN. In the case of improving QoS support in wireless technology, more researches are needed in the four fields: differentiation serving system, information extracting system based on PHY layer, resource reserving and CAC in MAC layer and IEEE 802.11 parameter tuning system. In further researches, simulation tools need to be upgraded to get accurate results in the future.

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