Modified EDCA Procedure to Improve the Quality of Service in WLAN

Thesis submitted in partial fulfillment of the requirements of the award of degree of

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Submitted By

Parminder Kaur

(Roll No. 601003018)

Under the supervision of

Mr. Singara Singh

Assistant Professor

School of Mathematics and Computer Applications

Thapar University

Patiala – 147004

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CERTIFICATE

I hereby certify that the work which is being presented in thesis entitled "**Modified EDCA procedure to improve Quality of Service in WLAN**", in the partial fulfillment of the requirements for the award of degree of Master of Technology in Computer Science and Applications submitted in School of Mathematics and Computer Applications (*SMCA*), Thapar University Patiala is an authentic record of my own work carried out under the supervision of Singara Singh Kasana and refers other researcher's work which are dually listed in reference section.

The material presented in this thesis has not been submitted for the award of any other degree of this or any other university.

(Parminder Kaur)
Roll No. 601003018
M.Tech (CSA)

This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

12.7.12
(Singara Singh)
Assistant Prof.
SMCA

Countersigned by

(Dr. S.S. Bhatia)
Professor &Head
SMCA
Thapar University
Patiala

(Dr. S. K. Mohapatra)
Dean (Academic Affairs)
Thapar University
Patiala

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Parminder Kaur

Roll No. 601003018

M.Tech (CSA)

ABSTRACT

Quality of service (*QoS*) is an internetworking issue. Quality of service is the ability to provide different priority to different applications, users, or data flows, or to guarantee a certain level of performance to a data flow. Characteristics of *QoS* which a network has to attain are reliability, delay, jitter, Bandwidth. There are various techniques for improving *QoS* such as Scheduling, Traffic Shaping algorithms, Resource reservation and Admission control. As 802.11 standard Medium Access Control (*MAC*) protocols is provided with two access methods DCF (Distributed Coordination Function) and PCF (Point coordination function). Original 802.11 standard was not designed to provide differentiation and prioritization based on the traffic type. In wireless environments, bandwidth is and channel conditions are time-varying and sometimes highly lossy. Many previous research works shown that what works well in a wired network cannot be directly applied in the wireless environment. It cannot provide *QoS* support for the increasing number of multimedia applications. Then, *IEEE* 802.11e *QoS* enhanced standard was proposed for 802.11 *WLAN*. The configuration of *QoS* parameters, however, is still an open research challenge, as the standard provides only a set of fixed recommended values, therefore lead to suboptimal performance.

In this thesis we attempt to study *QoS* management Techniques. The most common *QoS* provisioning strategy is to prioritize the different classes of traffic and make sure that high priority traffic gets preferential access to the channel. In this thesis thorough study of *MAC* protocol has been done and an improvement has been proposed in which the Contention Window and *AIFS* calculation function is varied in the non uniform manner for different *ACs* with an aim to improve the performance parameters. To demonstrate the effect of the modified *CW* and *AIFS* variation scheme simulation have been carried out using Qualnet Simulator designed by Scalar Network Technologies, Inc. After implementing the proposed modification a performance comparison has been carried out for parameters such as End to End Delay, Average Jitter and Average Throughput.

LIST OF ABBREVIATIONS

AC	Access Category
ACK	Acknowledgment
AP	Access Point
AIFS	Arbitrary Inter Frame Space
CA	Collision Avoidance
CFP	Contention Free Period
CP	Contention Period
CSMA	Carrier Sense Multiple Access
CW	Contention Window
CWmin	Contention Window minimum
CWmax	Contention Window maximum
DIFS	Distributed Coordination Function IFS
DCF	Distributed Coordination Function
EDCF	Enhanced Distributed Coordination Function
EIFS	Extended IFS
HC	Hybrid Coordinator
HCF	Hybrid Coordination Function
IEEE	Institute of Electrical and Electronics Engineers
IFS	Inter Frame Space
ISM	Industrial, Science, Medical
MAC	Media Access Control
MSDU	MAC Service Data Unit
APDCT	All Phase Discrete Cosine Transform

NAV	Network Allocation Vector
PC	Point Coordinator
PCF	Point Coordination Function
PIFS	Point Coordination Function IFS
QoS	Quality of Service
RF	Radio Frequency
RTS/CTS	Request to Send/Clear to Send
SIFS	Short Inter Frame Space
TC	Traffic Category
TXOP	Transmission Opportunities
WLAN	Wireless Local Area Network

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CHAPTER 1- INTRODUCTION

The term Internet is driven from word internetworking. The internet establishes global data communication systems between computers. Most of the communication media such as telephones, televisions, movies are redesigned and reshaped by internet. E-Mails are common way to communicate these days and also very common way to share files and data. In the beginning, people use to connect with internet via stationary computers which limited the internet usage. In 1997, a new standard IEEE802.11was introduced, which defines how to communicate with wireless network. Now we can connect to the internet using portable devices such as laptops, mobile phones, Personal Digital Assistants (*PDA*'s) rather stationary devices and Ethernet cables.

IEEE 802.11 is a set of standards for implementing Wireless Local Area Network (*WLAN*) computer communication in the 2.4, 3.6 and 5 GHz frequency bands. 802.11b and 802.11g use the 2.4 GHz. First version of 802.11 standards was released in 1997. It specifies three physical layer options: infrared (*IR*), frequency hopping spread spectrum (*FHSS*), and direct sequence spread spectrum (*DSSS*). FHSS and DSSS operate at the industrial, scientific and medical (*ISM*) band at 2.4 GHz and IR uses near visible light in 850 nm to 950 nm range for signal transmission. These three options do not become widely popular because of the low data rate, only 2 Mbps. Then in 1999 802.11b was introduced. In same year another amendment was released i.e. 802.11a. It operates in 5 GHz, and also uses OFDM modulation technique. Thus gives much higher data rates of 54Mbps. However 802.11a did not become widely used. Because its carrier frequency is so high which yields a shorter transmission range and can be easily blocked or attenuated by walls and other solid objects. Second reason is that it was not compatible with original 802.11 legacies.

The first mass used amendment to 802.11 standards is 802.11b. It operates at 2.4 GHz and supports the maximum data rate of 11 Mbps. 802.11b uses DSSS modulation technique of the original 802.11 standard and largely improves its data rate.

In 21stcentury as number of users is increasing usage of *WLAN* becomes popular. Need to send larger amount of data has also increased. In real time applications as telephony, video transmissions there may occur some problems. IEEE 802.11 which is most prevalent WLAN technology does not provide *QoS* support. In some cases, excessive latency can render an application such as VoIP or online gaming unusable. In some applications delivery of data in time is extremely important. Therefore in year 2005 new standard IEEE 802.11e was developed, which is amendment to the original IEEE 802.11. It introduced Quality of Service in IEEE 802.11 and its purpose is to increase performance in wireless LAN. For media access IEEE 802.11 MAC uses Distributed Coordination Function (*DCF*). But DCF alone is not capable for fulfilling QoS requirements in real time applications.

1.1 Quality of service

QoS is an internetworking issue. Quality of service is the ability to provide different priority to different applications, users, or data flows, or to guarantee a certain level of performance to a data flow. We can informally define quality of service as something a flow seeks to attain. In packet-switched networks, quality of service is affected by various factors, which can be divided into “human” and “technical” factors. Human factors include: stability of service, availability of service, delays, user information. Technical factors include: reliability, scalability, effectiveness, maintainability, grade of service, etc.

Many things can happen to packets as they travel from origin to destination, resulting in the following problems as seen from the point of view of the sender and receiver. Some of the parameters are as discussed below.

a) Low throughput

Due to varying load from other users sharing the same network resources, the bit rate (the maximum throughput) that can be provided to a certain data stream may be too low for real-time multimedia services if all data streams get the same scheduling priority.

b) Dropped packets

The routers might fail to deliver (drop) some packets if their data is corrupted or they arrive when their buffers are already full. The receiving application may ask for this information to be retransmitted, possibly causing severe delays in the overall transmission.

c) Errors

Sometimes packets are corrupted due to bit errors caused by noise and interference, especially in wireless communications and long copper wires. The receiver has to detect this and, just as if the packet was dropped, may ask for this information to be retransmitted.

d) Latency

It might take long time for each packet to reach its destination, because it gets held up in long queues, or takes a less direct route to avoid congestion. This is different from throughput, as the delay can build up over time, even if the throughput is almost normal. In some cases, excessive latency can render an application such as *VoIP* or online gaming unusable.

e) Jitter

Jitter indicates the variation in delay experienced in network. Packets from the source will reach the destination with different delays. A packet's delay varies with its position in the queues of the routers along the path between source and destination and this position can vary unpredictably. This variation in delay is known as jitter and can seriously affect the quality of streaming audio and/or video.

f) Out-of-order delivery

When a collection of related packets is routed through a network, different packets may take different routes, each resulting in a different delay. The result is that the packets arrive in a different order than they were sent. This problem requires special additional protocols responsible for rearranging out-of-order packets.

1.2 Characteristics of QoS

1.2.1 Reliability

Reliability specifies the guarantees that the protocol provides with respect to the delivery of messages. Lack of Reliability means losing of packet or acknowledgment. Loss refers to percentage of packets that fail to reach their destination. Loss can result from error in networks, corrupted frames and congested networks. Many of packets lost in healthy network dropped by networking devices as a means of avoiding congestion. Electronic mail, file transfer and internet access have reliable transmission than telephony or audio conferencing.

1.2.2 Delay

Delay or Latency refers to the time it takes for a packet to travel from the source to the destination. Different applications can tolerate delay in different degrees. Telephony, audio conferencing, video conferencing and remote login need minimum delay where as delay in file transfer and e-mail is less important.

1.2.3 Jitter

Jitter is variation in packets delay. Four packets depart at times 1,2,3,4 and arrive at 21, 22, 23, 24 have same time delay 20 time units, but if arrive at 21, 24, 21, 22 they have different delays.

High jitter - Long delay

Low jitter – Small delay

1.2.4 Bandwidth

Data rate supported by a network connection or an interface is known as Bandwidth. We can define Bandwidth in terms of bits per second (bps). Different applications need different bandwidths. In video conferencing we need to send million of bits per second.

There are primarily three possible ways by which we can improve Quality of Service.

1) Resource reservation: Flow of data needs resources such as a buffer, bandwidth, and *CPU* time. Quality of Service can be improved if these resources are reserved beforehand.
2) Admission control: Admission control refers to the mechanism used by a router, or a switch that accept or reject a flow based on predefined parameters called flow specifications.
3) Prioritization or assigning weights to different applications or data using techniques Inter Frame Space (*IFSs*) and Contention Window (*CWs*).

1.3 Wireless LAN

This chapter presents a comprehensive literature survey on different perspectives of Wireless Local Area Networks. Although Ethernet is widely used, wireless *LANs* are increasingly popular. Wireless Local Area Network links two or more devices using some wireless distribution method and provides mobility to move in the local coverage area without disconnected from network. Wireless networks can be seen as superior over wired networks as they are easy to install and flexible. However they are suffering from some problems like low Bandwidth, higher bit-error rates, higher delays and higher costs than wired networks. Before reading details of *WLAN*, first have an introduction of *WLAN* terms and components.

Wireless networks uses Radio Waves, Infrared Waves and Microwaves as transmission media.

1) Radio Waves:

Waves ranging from 3 kHz and 1GHz frequencies are known as Radio Waves. Radio Waves are Omni directional. When antennas transmit radio waves, they are propagated in all directions based on the wavelength, strength and purpose of transmission. On other side waves can be received by receiving antennas. The Omni directional characteristic of Radio waves makes them useful for multicasting, in which there is one sender but many receivers. FM radios, televisions, cordless phones.

2) **Microwaves:**

Microwaves have frequency between 1 and 300 GHz. These are unidirectional by nature. Thus sending and receiving antennas must be aligned. Antennas mounted on towers need to be in direct sight of each other i.e. Line-of-sight propagation. Microwaves of very high frequency cannot penetrate through walls. This characteristic can be a disadvantage if receiver devices are inside buildings. Therefore repeaters are required for long distance communications. Microwaves has applications such as Personal Area Network (Bluetooth), Wi-Fi, Wireless *WAN* such as 2G/3G Networks, Metropolitan Area Network (*WiMAX*), Satellite communications and Radar. But it becomes very famous in domestic use of microwave ovens.

3) **Infrared Waves:**

Infrared light is a part of electromagnetic spectrum that is shorter than Radio waves but longer than visible light. Infrared waves introduced with frequencies from 300 GHz to 400 THz. These can be used for short range communications. Infrared waves with higher frequencies cannot penetrate through walls. Thus a short range communication system in one room cannot interfere with another system in next room. Its applications are night vision equipment and TV Remote Controllers.

1.4 Terms used in 802.11 WLAN

1.4.1 Wireless LAN Station

Components that can connect into a wireless medium in a network are referred to as stations. All stations are equipped with wireless network interface card. Wireless Stations can be mobile devices such as laptops, personal digital assistants, *IP* phones or fixed devices such as desktops and workstations

1.4.2 Wireless Base Station

A Base station refers to the wireless access point for computers with wireless cards. It is basically the gateway between a wired network and the wireless network. It is controller over all stations in a *BSS*. All stations communicate via base station using polling function.

1.4.3 Types of services sets

According to IEEE standard Service Sets are broadly classified into Basic service sets and Extended service sets generally known as *BSS* and *ESS*. Details of both *BSS* and *ESS* are as follows.

1.4.3.1 Basic service set

The basic service set (*BSS*) is a set of all stations that can communicate with each other. Every *BSS* has an identification (*ID*) called the *BSSID*, which is the *MAC* address of the access point servicing the *BSS*. There are two types of BSS: Independent *BSS* and infrastructure *BSS*. An independent *BSS* is an ad-hoc network that contains no access points, which means they cannot connect to any other basic service set. An infrastructure BSS can communicate with other stations not in the same *BSS* by communicating through access points. *BSS* is building block of Wireless *LAN*, consists of stationary and mobile wireless stations that are optionally controlled by a base Station (called Access Point or AP).

BSS without *AP* is called an ad hoc Network.

BSS with *AP* is called an Infrastructure Network.

- **Ad hoc Network:**

An ad-hoc network is a network where stations communicate only peer to peer (P2P). There is no base and no one gives permission to talk. In certain circumstances the user will desire to build up Wireless *LAN* network without an Infrastructure (without an access point). This may include transfer between two notebook users. *IEEE* 802.11 addresses this need as an ad hoc mode, in this there is no access point and point of functionality is provided by end user.

- **Infrastructure network:**

Infrastructure BSS is part of 802.11 Wireless Network Standard. It consist both access points and station. Communication between stations can be performed via Access Points. Distributed coordinated function is mandatory in infrastructure and point coordinated function is optional. Figure 1 shows both Ad hoc and Infrastructure BSS.

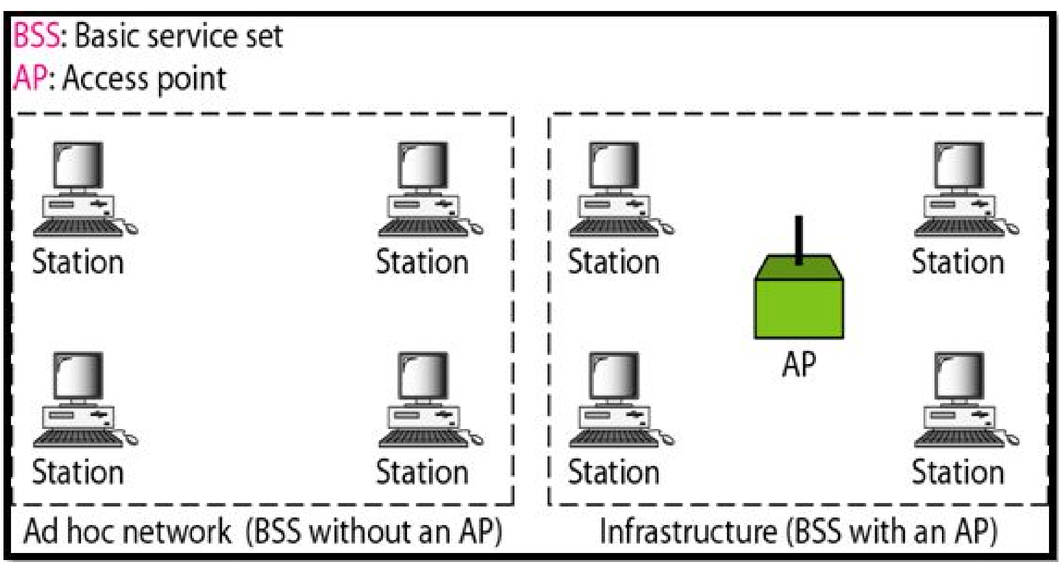

Figure 1: Ad hoc and Infrastructure BSS [13]

1.4.3.2 Extended service set

An Extended Service Set (*ESS*) is a set of two or more connected *BSSs* with *APs* (Access points). In an *ESS*, one or more *BSS*s are connected by a distribution system which is generally a wired *LAN*. However communication between two different BSSs usually occurs via two *APs*. Figure 2 shows architecture of ESS and Distribution System. Extended Service Set uses two types of stations mobile and stationary. Mobile stations are normally inside a *BSS*. Mobile stations can belong to more than *BSS* at same time. The stationary stations are the Access Points that are part of a wired *LAN*. The idea is similar to communication in a cellular network if we consider each *BSS* to be a cell and each *AP* to be a base station. Each *ESS* has an *ID* called the *SSID* which is a 32-byte (maximum) character string.

1.4.3.3 Distribution system

A Distribution System (*DS*) connects access points in an extended service set. The concept of a *DS* can be used to increase network coverage through roaming between cells. *DS* can be wired or wireless. Current wireless distribution systems are mostly based on *WDS* or *MESH* protocols, though other systems are in use.

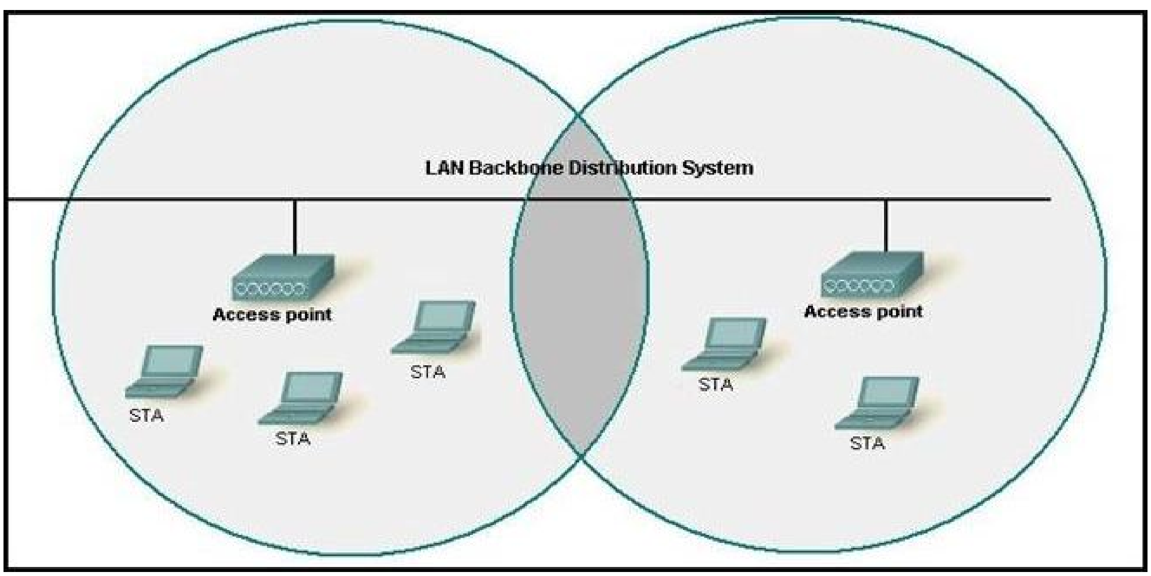

Figure 2: ESS and Distribution System

1.4.3.4 Station types

No Transition - station with no mobility or moving inside a *BSS.*

BSS-Transition- station with mobility from one *BSS* to another *BSS*.

ESS- Transition- station with mobility from one *ESS* to another *ESS*.

1.5 Services

IEEE 802.11Wireless *LAN* provides nine services divided into two categories. There are five distribution services and four services stations. These distribution services are provided by the Base Stations and deal with station mobility as they enter and leave the cells. Attaching them to and detaching from base stations.

1.5.1 Distribution services

i. **Association**: This service is used by mobile stations to connect themselves to base stations. Generally, it is used just after a station moves in radio range of a base station. Upon arrival it announces its identity and capabilities. Capabilities include data rate supported, polling information need for *PCF* services and power management requirements. The base station may accept or reject the mobile station. After acceptance (if *BS* accepts) station must authenticate itself.

ii. **Disassociation:** Station or *BSS* use this service before leaving, either the Base Station or Station can disassociate, shut down or breaking the relationship.

iii. **Reassociation:** A station may change its preferred base station using this service. Reassociation is useful for mobile stations that move from one cell to another. If it is used correctly no data will be lost. Station change its preferred base stations without data lost as consequences of the handover

iv. **Distribution:** This service determines how to route the frames sent from a base station. If the destination is local to the base station frames sent out directly in air. If within same BSS then sent directly otherwise forward over the wired network.

v. **Integration:** Integration handles translation from 802.11 to non 802.11 networks. If a frame has to send through a non-802.11 network with a different addressing scheme or frame format, this service handles the translation from 802.11 format to the format required to the destination network.

1.5.2 Services Stations:

i. **Authentication:** Because wireless communication can easily can be sent or received by unauthorized stations, a station must authenticate itself before it is permitted to send data. After a mobile station has been associated by the base station, the base station sends a special challenge frame to it to see if the mobile station knows the secret key that has been assigned to it. It proves its knowledge of the secret key by encrypting the challenge frame and sending it back to base station, but work to repair this defect in the standard is underway.

ii. **Deauthentication:** when a previously authenticated station wants to leave the network, it is deauthenticated. After deauthentication it may no longer use the network.

iii. **Privacy:** To keep confidential to the information sent over the Wireless *LAN*, it must be encrypted. This service manages the encryption and decryption.

iv. **Data Delivery:** 802.11 provide a way to transmit and receive data. Since 802.11 is modelled on Ethernet and transmission over the Ethernet is not guaranteed to be 100 percent reliable, transmission over 802.11 is not guaranteed to be reliable either. Higher layers must deal with detecting and correcting errors.

1.6 Types of Frames

In Wireless LAN defined by *IEEE* 802.11 has three categories of frames: Management frames, Data frames and Control frames.

Management frames: Management frames are used for initial communication between stations and access points.

Data Frames: data frames are used for carrying data and control information.

Control frames: Control frames are used for control access to medium and *ACK* frames. Basically used to gain Access to the channel and acknowledging the frames. Further three types of Control frames are:

Request to send (*RTS*)

Clear to send (*CTS*)

Acknowledgment (*ACK*)

1.7 InterFrame spacing

SIFS (Short InterFrame spacing):

It is used to allow the parties in a single dialog the chance to go first. This include letting the receiver send a *CTS* to respond to *RTS*, letting the receiver send a acknowledgment

(*ACK*) for the fragment of full data frame, and letting the sender send a fragment burst transmit the next fragment without having to send *RTS* again.

PIFS (PCF InterFrame spacing):

The base station may send a beacon frame or poll frame. This mechanism allows a station sending a data frame and a fragment sequence to finish its frame without anyone else getting in the way, but gives a chance to base station to grab a channel.

DIFS (DCF InterFrame spacing):

If base station has nothing to say and time *DIFS* elapses, any station may attempt to acquire the channel to send a new frame. If at same time station wants to use *DCF* and *AP* wants to use *PCF*, the *AP* has higher priority. Once the back-off interval has expired the STA begins the transmission. If the transmission is not successful, a collision is considered to have occurred. In this case the *CW* is doubled and a new backoff procedure starts again with the latest backoff counter value. The updated new *CW* value is $CW = 2(CW + 1) - 1$ with an upper limit of max *CW* [4]. This reduces the collision probability in case of many *STA's* attempting to access the channel.

1.8 Scope of IEEE 802.11

IEEE 802.11 protocol covers *MAC* and Physical layer.

1.8.1 802.11 Physical Layer

Following are the specifications of 802.11 Physical Layer.

IEEE 802.11 FHSS

IEEE 802.11 *FHSS* uses the frequency-hopping spread spectrum (*FHSS). FHSS* uses the 2.4-GHz ISM band. The band is divided into 79 sub bands of 1MHz and some guard bands. A pseudorandom number generator selects the hopping sequence [2]. The modulation scheme is in this specification is either two level *FSK* (Frequency Shift Key) or four level FSK with 1-2 bits/baud, which results in a data rate of 1 or 2 Mbps.

IEEE 802.11 DSSS

IEEE 802.11 *DSSS* uses a direct sequence spread spectrum (*DSSS*). *DSSS* uses the 2.4-GHz *ISM* band. The modulation scheme in this specification is PSK at 1 Mbaud/s. System allows 1 or 2 bits/baud which results in the data rate if 1 or 2 Mbps.

IEEE 802.11 Infrared

IEEE 802.11 Infrared uses Infrared light in range of 800 to 950 nm. The modulation technique is used Pulse Position Modulation (*PPM*). For 1 Mbps data rate 4-bit sequence is first mapped into 16-bit sequence in which only one bit is set to 1 and rest are set to 0. For 2-Mbps data rate a 2 bit sequence is first mapped into 4 bit sequence in which only one bit is set to 1 and rest are set to 0. The mapped sequences are converted into optical signals; the presence of light specifies 1, the absence of the light specifies 0.

IEEE 802.11a OFDM

IEEE 802.11a *OFDM* describes the orthogonal frequency –division multiplexing (*OFDM*) method for signal generation in a 5-GHz ISM band. *OFDM* is similar to *FDM* with one major difference: that all the subbands are used by one source at a given time. Sources contend with one another at Data Link Layer for access. The band is divided into 52 subbands, with 48 subbands for sending 48 groups of bits at a time and 4 subbands for control information. Dividing the band into subbands diminishes the effects of interference. If the subbands are used randomly, the security can be increased. The common data rate is 18 Mbps (*PSK*) and 54 Mbps (*QAM*).

IEEE 802.11b DSSS

IEEE 802.11b *DSSS* describes high data rate direct sequence spread spectrum (*HR-DSSS*) method for signal generation in the 2.4 GHz *ISM* band. *HR-DSSS* is similar to *DSSS* except for the encoding method, which is called Complementary Code Keying *(CCK)*. *CCK* encodes 4-8 bits to one *CCK* symbol. To be backward compatible with the *DSSS*, *HR-DSSS* defines four data rates: 1, 2, 5.5, and 11 Mbps. The first two use the same modulation technique as *DSSS*. The 5.4 Mbps uses the *BPSK* and transmits at 1.375 Mbaud/s with 4-bit *CCK* coding. The 11 bit version uses *QPSK* and transmits at 1.375 Mbaud/s with 8-bit *CCK* coding.

1.8.2 802.11 Mac layer

The primary function of a *MAC* protocol is to define a set of rules and give the stations a fair access to the channel for successful communication. Many *MAC* Protocols provide the standardized Medium Access [10]. Medium access control enables multiple wireless devices to share a common transmission medium via a carrier sense protocol similar to Ethernet. This protocol enables a group of wireless computers to share the same frequency and space. A wireless *LAN* Media Access Control protocol provides reliable delivery of data over somewhat error-prone wireless media.

1.9 Access methods

MAC Layer defines 2 access methods

1. Distributed coordination Function (*DCF*).
2. Point coordination Function(*PCF)*

Beyond standard functionality usually performed by *MAC* Layers, 802.11 *MAC* performs other functions that are related to upper layer protocols, such as fragmentation, Retransmission and acknowledgments.

1.9.1 Distributed Coordination Function (*DCF*)

DCF is the basic medium access mechanism for both ad hoc and infrastructure mode. *DCF* is a distributed medium access scheme based on carrier sense multiple accesses with time thus relies on *CSMA/CA* as access method. *CSMA/CA* Protocol is designed to reduce probability of collision between multiple stations accessing a medium. *CSMA/CA* protocol works as follows: when a packet arrives at the front of transmission queue, with a channel found idle for an interval of time more than Distributed Inter frame Space. In *DCF*, the station may proceed with its transmission if the medium is sensed to be idle for an interval larger than the Distributed Inter Frame Space (DIFS). If the medium is busy, the station defers until a DIFS is detected and then generate a random back-off period before transmitting. The back-off timer counter is decreased as long as the channel is sensed idle [10]. Station waits until backoff timer reaches to zero and then transmits frame. For every transmission, backoff timer is uniformly chosen within [0, *CW*-1]. Initially *CW* is equal to minimum backoff window size *CWmin* [4]. Every time the collision occurs and transmission fails *CW* is doubled until it reaches to its maximum backoff window size i.e. *CWmax*. After every successful transmission *CW* will be reset to initial value *CWmin*. For each successful reception of a packet, the receiving queue stations immediately acknowledges by sending an *ACK* packet. *ACK* packet is transmitted after a Short Inter Frame Space (*SIFS*). If an *ACK* packet is not received after the data transmission, the packet is retransmitted after another random backoff.

1.9.1.1 RTS/CTS Mechanism:

To overcome the hidden node problem *RTS/CTS* scheme has been devised. First we will study briefly about the hidden node problem.

Hidden Node Problem: Figure 3 shows an example of hidden node problem. Station B has its transmission range shown by left oval, every station in this range can hear any signal transmitted by station B. Station C has a transmission range by another oval, every station in this range can hear any signal transmitted by C. Station C is outside the transmission range of B. Likewise, station B is outside the transmission range of C. Station A, however is in the area covered by both B and C [13].

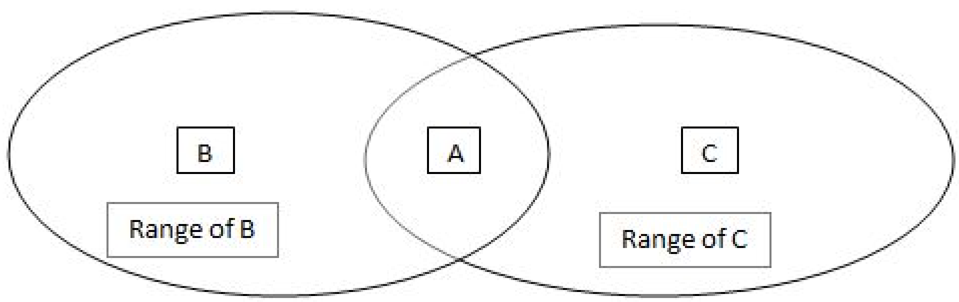

Figure 3: Hidden Node Problem

Assume that station B is sending data to station A. In the middle of the transmission, station C has data to send to station A. However station C is out of B's range and transmission from B cannot reach C. Therefore C thinks that medium is free. Station C sends its data to A, which results in collision A because this station is receiving data from B at same time. Thus we say station B is hidden from C and vice versa. A hidden node problem reduces the capacity and performance of the network because of occurrences of collisions.

Solution to this problem is to use handshake frames (*RTS/CTS*). Whenever a station has a packet to transmit, it must listen the medium for the *SIFS* time period. If medium is idle for *SIFS* then transmission of RTS held after backoff timer, otherwise deferred until idle condition satisfies. After receiving *RTS*, destination waits *SIFS* time and then send another control frame *CTS*. Other stations defer their transmission with *NAV*. If *CTS* arrives within time then the channel is reserved for transmission of data, Source sends data after waiting period *SIFS*. Receiver responses back with *ACK* after waiting *SIFS*. If an *ACK* packet is not received after the data transmission. The packet is retransmitted after another backoff.

1.9.1.2 Network Allocation Vector:

Other Stations defer their data sending if one station acquires the access on medium. This feature is called Network Allocation Vector (*NAV*).

When a station sends an *RTS* frame, it includes other information also like duration of time that how long it will take to acquire the medium for transmission. In that interval, other stations that are affected by this transmission create a timer called Network Allocation Vector that shows how much time must pass before these stations are allowed to check the channel for idleness. Each time a station accesses the system and sends an *RTS* frame, other stations start their *NAV*. In other words, each station, before sensing the physical medium to see if it is idle, first checks its *NAV* to see if it is expired. Figure 4 explains the concept of *NAV* and working of Distributed coordination Function.

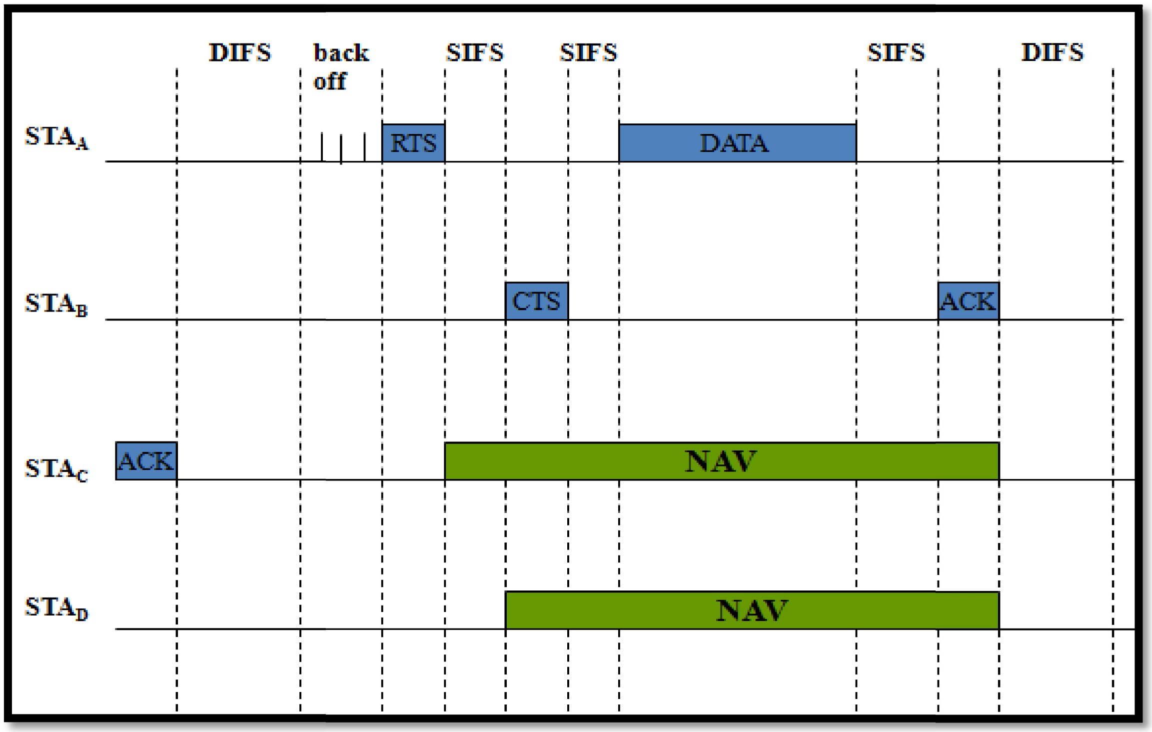

Figure 4: Working in DCF Mode

The protocol starts when A decides it wants to send data to B. It begins by sending an RTS frame to B to request permission to send it a frame. When B receives this request, it may decide to grant permission in which case it sends a *CTS* frame back. Upon receipt of the *CTS*, A sends its frame and starts its *ACK* Timer. Upon correct receipt of the data frame, B responds with an *ACK* frame, terminating the exchange. If A's *ACK* timer expires before the *ACK* gets back to it, the whole protocol is run again.

Now let us consider this exchange from the viewpoints of C and D. C is within the range of A, so it may receive the *RTS* frame. If it does, it realizes that someone is going to send data soon; it desists from transmitting anything until exchange is complete. From the information provided in the *RTS* Frame, it can estimate how long the sequence will take, including the final *ACK*, so it asserts a kind of virtual network busy for itself, indicated by *NAV* (Network Allocation Vector). D does not hear the *RTS* but it hear the *CTS*, so it also asserts the *NAV* signal for itself. Note that the *NAV* signals are not transmitted; they are just reminders to keep quiet for a certain period of time.

Due to high bit error rates in *WLAN* because of interference, smaller frames have higher probability of being transmitted without any error than bigger frames. Thus the fragmentation mode was added to the 802.11 *MAC* mechanism as shown in Figure 5. Big frames are divided into smaller fragments. Each fragment is transmitted and acknowledged separately. After a station has the right to access the medium, it is allowed to send several Data and *ACK* frames separated by *SIFS*. Therefore no other station is able to interrupt the communication.

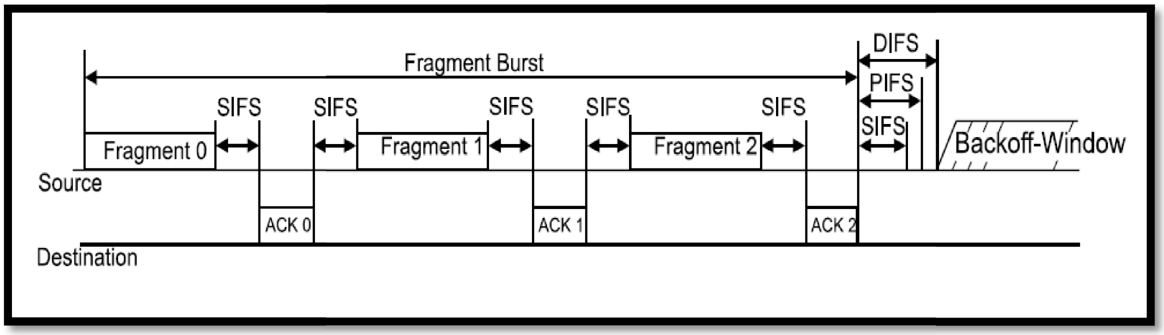

Figure 5: Fragmentation in 802.11

1.9.2 Point Coordination Function (PCF):

PCF uses a centralized polling method, which requires the *AP* as a point coordinator (*PC*). The stations request the *PCF* mode, to get associated with the Point Coordinator during the contention period (*CP). PCF* supports time bound service in IEEE 802.11 standard to let *STA*'s have contention free access to the wireless medium, coordinated by the *PC*. With *PCF*, the channel alternates between the contention free period (*CFP*) and contention period (*CP*) for the *PCF* and *DCF* mode respectively. The *PCF* provides synchronous service that basically implements polling based access. It has a higher priority than the *DCF*, because the period during which the PCF is used protected from the *DCF* contention via, the Network Allocation Vector (*NAV*) set. If at same time station wants to use *DCF* and *AP* wants to use PCF, the AP has higher priority. This is an optional access method, implemented in infrastructure network. It is mostly used in time sensitive transmission*. PCF* has centralized, contention free polling access method. As priority of *PCF*, stations use only *DCF* may not gain access to the medium, this is called repetition interval. During repetition interval *PC* (point controller) can send poll frame, receive or send, data or *ACK*. At the end, *PC* sends *CF* (contention free end) end frame to allow contention based station to use medium. A super frame is formed by the *CP* and *CFP* together. A beacon frame is generated at regular beacon frame intervals called target beacon transmission time (*TBTT*) by the access point. The value of the *TBTT* is announced in the beacon frame. The beacon frame, which is used to maintain synchronization among local timers in the stations and to deliver protocol related parameters, is used to indicate the beginning of the super frame.

1.10 Limitation of IEEE 802.11 legacy

1.10.1 QoS Limitation of DCF

DCF supports only the best effort service and does not provide any *QoS* guarantees. Typically, time-bounded services such as voice over *IP* or audio/video conferencing require specified bandwidth, delay, and jitter, can tolerate some losses.

In *DCF* mode, all the *STA's* in one *BSS* compete for the resources and channel with same priorities where as priorities should be assigned depending on the type of data flow [11]. There is no differentiation to guarantee bandwidth, packet delay and jitter for high priority *STAs* or multimedia flows [16].

1.10.2 QoS Limitation of PCF

Although *PCF* has been designed to support time bounded multimedia applications, this mode has some problems that lead to poor *QoS* performances. All the communication between two *STAs* in the same *BSS* has to go through the *AP* (Access Point), thus some of the channel bandwidth is wasted. As traffic increases a lot of channel resources are wasted. The cooperation between *CP* and *CFP* modes may lead to unpredictable beacon delays. No mechanisms for the stations to communicate their QoS requirements to the *AP*.

1.11 802.11e Quality of Service enhancement in Wireless LAN

The original 802.11 standard was not designed to provide differentiation and prioritization based on the traffic type, thus providing less than optimal user experience for voice and video over *WLAN* applications. Voice applications require no dropped calls or bad connections. Video/audio applications require enough bandwidth to maintain high quality video/audio streams [23]. Email and file-sharing applications require ensuring delivery of error-free files. To fulfil these requirements, the IEEE 802.11e has added several QoS features and enhancements to *WLAN*.

The IEEE 802.11e has been approved as a standard that defines *QoS* mechanisms for *WLAN*. The 802.11e enhances the *DCF* and the *PCF*, through a new coordination function: the Hybrid Coordination Function (*HCF*). Within the *HCF*, there are two methods for channel access, similar to those defined in legacy 802.11 *MAC*: *HCF* Controlled Channel Access (*HCCA*) and Enhanced Distributed Channel Access (*EDCA*). Both *EDCA* and *HCCA* define Traffic Categories *(TC*). It differentiates traffic types and sources. It is considered to be important for delay-sensitive and bandwidth- sensitive applications. For Example, emails can be assigned to low priority class, and voice over Wireless LAN could be assigned to higher priority.

1.11.1 Enhanced distributed channel access

Enhanced Distributed coordination function (*EDCA*) provides differentiated and distributed access to the Wireless medium. Each frame received from upper layers is assigned with its user priority (*UP*). After receiving each frame the *MAC* layer maps the frame into an Access Category (*AC*) depending on its user priority it carries. The levels of priority in *EDCA* are called *AC*. Each *AC* has a different priority or preference of access. One or more Ups can be assigned to one *AC*. *EDCA* specifies up to eight ACs to support the user Priorities [1]. Each QoS-enhanced *STA* (*QSTA*) has 4 queues (*ACs*), to support 8 *UPs* as given in Table 1. Each *AC* queue works as an independent *DCF STA* and uses its own backoff parameters.

Table 1: Access Categories and user priorities

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

The *EDCA* has Access parameters for controlling channel access such as minimum and maximum Contention Window size (CWmin and CWmax), Arbitration Inter Frame Space and Transmission Opportunity limit (*TXOP* limit). These parameters can be used in order to differentiate the channel access among different priority traffic as clearly shown in Figure 7. When number of stations increases in *BSS* there is more than one *AC* finishing the backoff at the same time, virtual collision occurs.

User Priorities are generally mapped into four Access Categories. With *EDCA*, high priority traffic has a higher chance of being has 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 inter-frame space (*AIFS*) for higher priority packets. For different Traffic Category different *AIFS* value is assigned. For low priority *TC AIFS* has higher value in comparison to high priority *TC*. Figure 6 has mentioned Inter Frame Space relationship for different Traffic Categories. The exact values depend on the physical layer that used to transmit the data. A *TXOP* is a bounded time interval during which a station can send as many frames as possible. It is defined as the interval during which a station has the right to initiate the transmissions [3]. It is characterized by a starting time and maximum duration called *TXOP* limit. Depending on the *TXOP* limit station can transmit one or more *MAC s*ervice data units (*MSDUs*). If a frame is too large to be transmitted in a single *TXOP*, it should be fragmented into smaller frames. The use of *TXOPs* reduces the problem of low rate stations gaining an insufficient amount of channel time in the legacy 802.11 *DCF MAC*. A *TXOP* time interval of 0 means it is limited to a single *MAC* service data unit or *MAC* management protocol data unit (*MMPDU*).

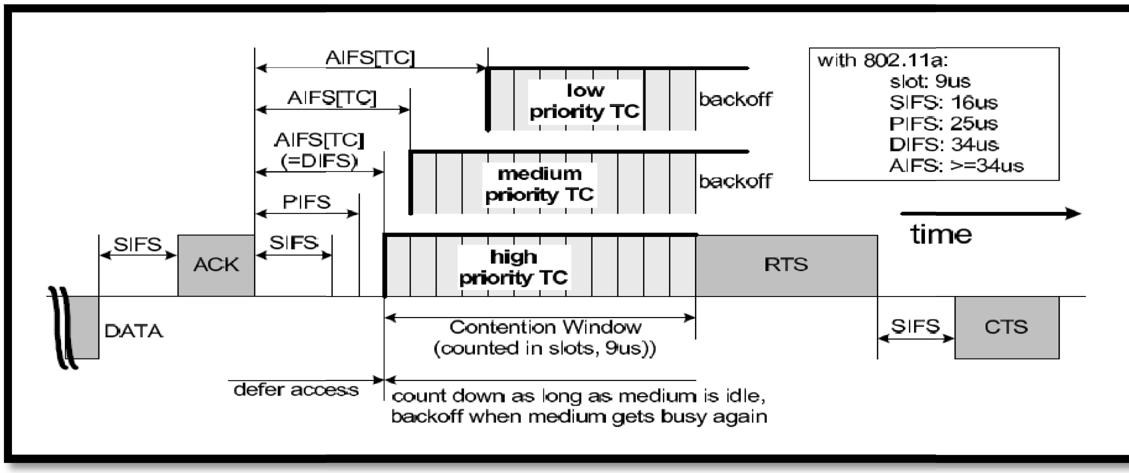

Figure 6: IFS relationship in 802.11e

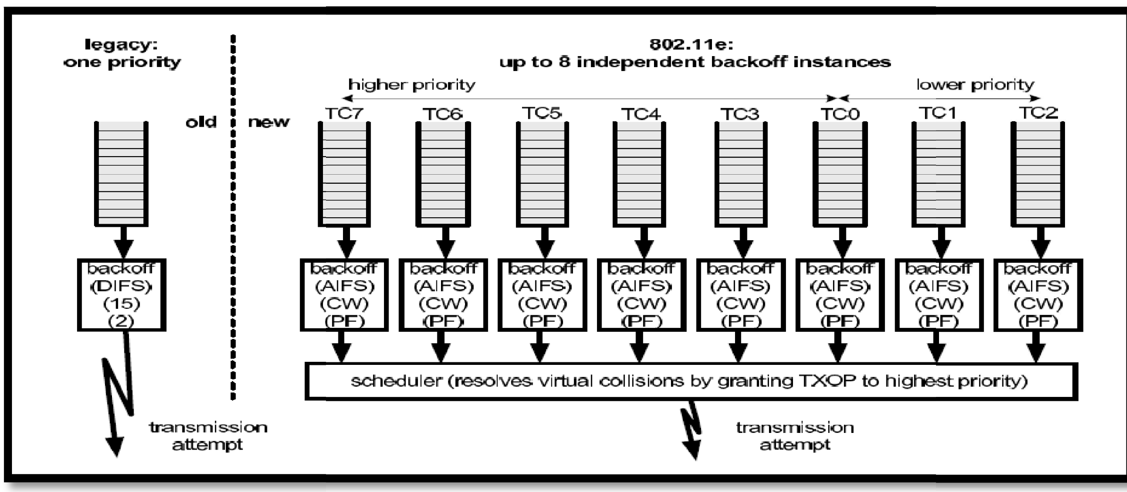

Figure 7: IEEE 802.11e MAC Structure

In *DCF* backoff slot begins after *DIFS* from the end of the last indicated busy medium, whereas in *EDCA* backoff slots begin at different intervals according to the *AC* of the traffic queue. The duration of the inter frame space is given by:

AIFS[i] = SIFS + AIFSN* slot time

The CWmin and CWmax values are calculated from aCWmin and aCWmax values, respectively, that are defined for each physical layer supported by 802.11e. *EDCA* ensures better services to high priority classes while offering a minimum best effort service for low priority traffic.

Calculation procedure of Contention window for different Access Categories is described in Table 2.

Table 2: CW for different ACs

Access Category	CWMin	CWMax
AC_BK	aCWmin	ACWmax
AC_BE	aCWmin	ACWmax
AC_VI	(aCWmin+1)/2-1	ACWmin
AC_VO	(aCWmin+1)/4-1	(aCWmin+1)/2-1

Default *EDCA* Parameters for Access Categories are mentioned in Table 3.

Table 3: Default *EDCA* parameters

Access Category	CWmin	CWmax	AIFSN
AC_BK	15	1023	7
AC_BE	15	1023	3
AC_VI	7	15	2
AC_VO	3	7	2

1.11.2 HCF Controlled Channel Access

The *HCF* (hybrid coordination function) 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*. The other 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 *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 *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 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.

Different 802.11 Working groups:

- 802.11a (54Mpbs in 5GHz Band)
- 802.11b (11 Mbps in 2.4 GHz Band)
- 802.11c Wireless AP Bridge Operations
- 802.11d Internationalization
- **802.11e (QoS)**
- 802.11f Inter-vendor AP hand-offs
- 802.11h Power control for 5Ghz region
- 802.11g (54Mbps in 2.4 GHz Band)
- 802.11i (Security)

CHAPTER 2- LITRATURE SURVEY

The number of wireless networks and devices increasing day by day as users prefer to use wireless technology due to its flexible use. The emergence of mobile devices or mobile nodes allows the users to access the network when they are on move. With the demand for providing high speed mobile multimedia and supporting diversified requirements of users, Wireless *QoS* becomes more and more indispensable. Many simulation and analysis work have been done related with the performance of IEEE 802.11e. Different algorithms have been proposed to improve parameters such delay, throughput, jitter and congestion control by researchers.

Banchs *et al.* [5] enhanced *QoS* of network supported by 802.11e *EDCA* by using a parameter configuration algorithm to provide guaranteed Throughput, and the optimal parameter selection is analyzed to efficiently utilize network resources. In [6] the Mac level performance of throughput in 802.11e has been analyzed by executing the simulations by Ferre *et al*.

Vassis *et al.* [7] proposed an analytical model for the performance evaluation of IEEE 802.11e *EDCA* scheme under finite load conditions on the basis of various instances of delay metric (i.e., media access delay, queuing delay and total delay). The simulation results show that the analytical estimated instances of the delay metric are almost accurate. The paper exhibits that concerning the delay of serving classes, *EDCA* compared to the conventional *DCF*, favors high priority classes against low priority ones, while almost does not affect the behavior of medium ones.

Banchs *et al.* [8] proposed a wireless QoS architecture to analyze the delay behavior of the *EDCA* mechanism of IEEE 802.11e. Simulation results validate the accuracy of our analysis. They have validated the accuracy of our analysis by comparing analytical results against simulations. Experiments are performed for a varying number of stations (in the x axis). For all tests, a fixed packet length of 1500 bytes, the system parameters of the IEEE 802.11a physical layer and the no *RTS/CTS* option have been used.

In [9] Xiao *et al.* have described backoff based priority schemes for IEEE 802.11e standard by differentiating the minimum backoff Window size, backoff window increasing factor and the retransmission limit. In this paper an analytical model has been proposed to derive saturation throughputs, saturation delays, and frame dropping probabilities of different priority classes. Simulations have validated the analytic results. For all three backoff-based metrics i.e. the initial window size, the retry limit, and the backoff window-increasing factor, one class can steal bandwidth from another if the latter one increases the metric value and the total throughput increases a little.

Sehrawat *et al.* [12] have evaluated the capability of *QoS* support in Enhanced Distributed Channel Access (*EDCA*) mechanism of the IEEE 802.11e standard, which is the medium access control (*MAC*) enhancements for *QoS* support in 802.11.*EDCA* mechanism allow prioritized medium access for applications with high *QoS* requirements by assigning different priorities to its four access categories. Its performance is evaluated under real time audio and video traffic through simulations using Network Simulator-2(NS 2), parameters like mean delay, throughput are calculated and graphs has been plotted. With *EDCA* mechanism, network capacity is effectively increased to better support real-time audio and video transmissions.

Park *et al.* [14] proposed a fair *QoS* agent (*FQA*) to simultaneously provide per-class *QoS* enhancement and per-station fair channel sharing in *WLAN* access networks. *FQA* implements two additional components above the 802.11 *MAC*: a dual service differentiator and a service level manager. The former is intended to improve *QoS* for different service classes by differentiating service with appropriate scheduling and queue management algorithms, while the latter is to assure fair channel sharing by estimating the fair share for each station and dynamically adjusting the service levels of packets. *FQA* assures (weighted) fairness among stations in terms of channel access time without decreasing channel utilization. Furthermore, it can provide quantitative service assurance in terms of queuing delay and packet loss rate.

Sai *et al.* [15] have addressed the important problem of delay sensitive transmission of video over IEEE 802.11a/e *WLAN*s. They focused on the admission control scheme that uses a new parameter called “channel burstiness” to model the characteristics of the time-varying wireless channel and then use effective bandwidth calculations to admit the optimal number of video streams. They explained with simulation how different access mechanisms in IEEE 802.11e can provide the necessary QoS for the admitted video applications. Additionally, they have highlighted the differences between the two modes, *EDCA* and *HCCA*, in the IEEE 802.11e *WLAN* system and show the relative merits and demerits. They introduced the concept of subflow that enhances the quality of video at the receiver in the presence of errors.

Liau *et al.* [17] proposed a priority setting, fairness and cross layer design and designed four scheduling schemes for *QoS* oriented Wireless *LAN*. The concept of deficit count and allowance are proposed in this paper to provide better *QoS* and fairness. Using multiple deficit count to Inter Frame Space (*IFS*) and allowance to *IFS* mapping for different priorities, enhanced distributed deficit round robin (*EDDRR*) and enhanced distributed elastic round robin (*EDERR*) schemes are designed to reduce (or even eliminate) possible collisions.

Zhalehpour *et al.* [18] have proposed two adaptive backoff algorithms entitled *TBA* and *SBA* algorithms and have evaluated their performances. *TBA* and *SBA* backoff algorithms provide the *QoS* enhancement in Mobile Ad-hoc Networks. In *TBA* backoff algorithm by means of statistical sampling of various successful and unsuccessful transmissions, author adjust the traffic parameters based on traffic loads status but this algorithm is not useful when there are different size of packets on the network such as VoIP.

Serrano *et al.* [21] introduced a new algorithm which, gives the throughput and delay requirements of the stations that are present in the *WLAN*, and computes the optimal configuration of the *EDCA* parameters. Paper first present a throughput and delay analysis that provides the mathematical foundation upon which our algorithm is based. This analysis is validated through simulations of different traffic sources (both data and real time) and *EDCA* configurations. Authors proposed a mechanism to derive the optimal configuration of the *EDCA* parameters such as throughput and delay. the effectiveness of the configuration has been compared against i) the recommended values by the standard, ii) the results from an exhaustive search over the parameter space, and iii) previous configuration proposals.

CHAPTER 3 - INTRODUCTION TO QUALNET – NETWORK SIMULATOR

3.1 Introduction

QualNet is network modeling software that predicts performance of networking protocols and networks through simulation. Qualnet is a cornerstone of Virtual Networking Labs that enables the deployment of applications in Wireless, Wired and mixed Network platforms. Using simulation allows you to reproduce the unfavorable conditions of networks in a controllable and repeatable lab setting. Scalability in Qualnet is necessary for prediction of large network behavior of thousands of nodes. High fidelity network models are a necessity for detailed and accurate network performance prediction, but they are hard to support due to the computational load they create. Extensibility, or the ability to interface to other simulations and real networks, greatly increases the value of communication simulations. The QualNet simulation engine is extremely scalable and can accommodate high fidelity models of networks of thousands of nodes.

QualNet makes good use of computational resources and models large scale networks with heavy traffic and mobility in reasonable simulation times. QualNet Parallel Developer takes speed and scalability to new levels through the use of dual-core systems, clusters, and supercomputers.

3.2 Key Benefits of QualNet

1) **Speed:** QualNet can support real-time and faster than real-time simulation speed, which enables software-in-the-loop, network emulation, hardware-in-the-loop, and human-in-the-loop exercises.

2) **Scalability:** QualNet supports thousands of nodes. It can also take advantage of parallel computing architectures to support more network nodes and faster modeling. Speed and scalability are not mutually exclusive with QualNet.

3) **Model Fidelity:** QualNet offers highly detailed models for all aspects of networking. This ensures accurate modeling results and enables detailed analysis of protocol and network performance.

4) **Portability:** QualNet runs on a vast array of platforms, including Linux, Solaris, Windows *XP,* and Mac *OS X* operating systems, distributed and cluster parallel architectures, and both 32- and 64-bit computing.

5) **Extensibility:** QualNet connects to other hardware & software applications, such as *OTB*, real networks, and *STK*, greatly enhancing the value of the network model.

3.3 QualNet Simulator

The Animator uses the QualNet simulator as its processing engine to run a scenario. QualNet simulator is an advanced discrete-event simulator that enables fast, scalable, and hi-fidelity modeling of networks. The QualNet simulator can also be run from command-line. This enables advanced protocol designers and network modelers/planners to use other command-line tools like shell scripts and remote execution to quickly modify and execute the scenarios with different parameter and model values. The command-line mode also runs a lot faster since the graphical events do not have to be animated, but produces the same results as the Animator since both uses the same simulation engine. Analyzer and Packet Tracer can still be used for detailed analyses of the simulation results after the simulator has run. Figure 8 shows the most commonly used toolbars and menus in QualNet GUI.

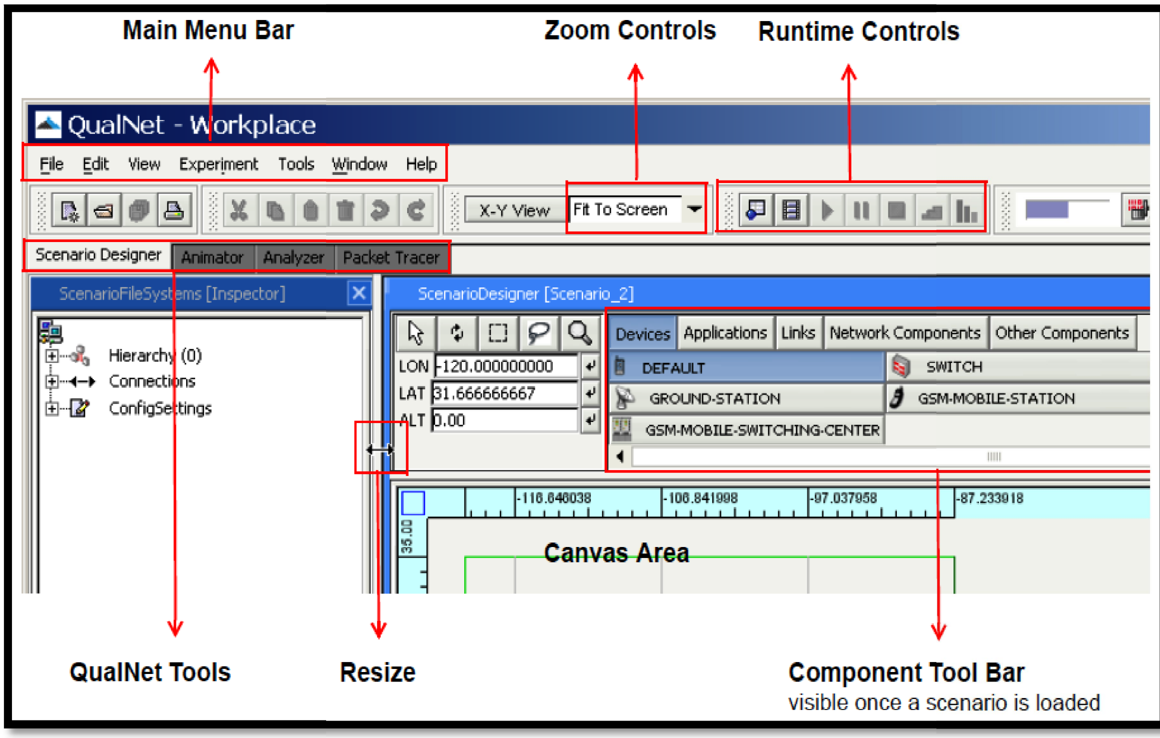

Figure 8: IEEE 802.11e MAC Structure

3.4 QualNet Developer Architecture

Figure 9 illustrates the QualNet Developer architecture. A high-level description of the various components is provided below.

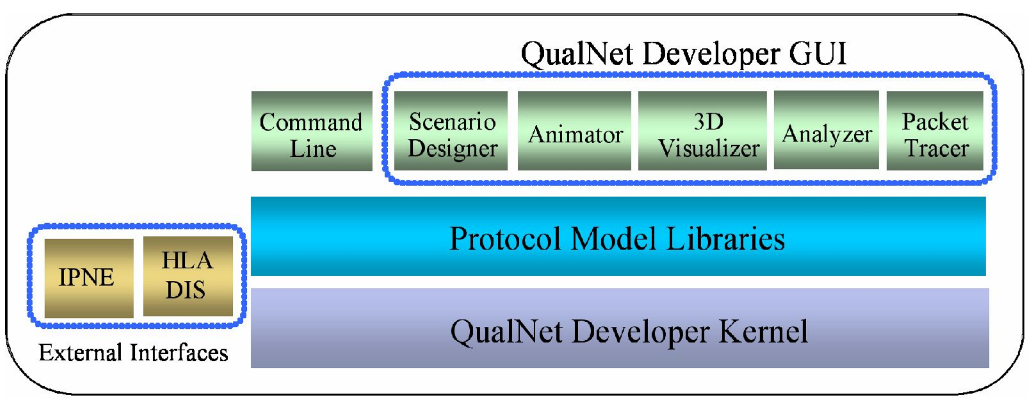

Figure 9: QualNet Developer Architecture [22]

3.5 QualNet Developer Kernel

The kernel of QualNet Developer is an *SNT*-proprietary, parallel discrete-event scheduler [22]. It provides the scalability and portability to run hundreds and thousands of nodes with high-fidelity models on a variety of platforms, from laptops and desktops to high performance computing systems. Users do not directly interact with the kernel, instead they:

Use the QualNet Developer *GUI* or Command Line Interface to run network scenarios on the simulation kernel, or

Develop protocol models using the QualNet *API* which interacts with the kernel.

3.6 QualNet Model Libraries

QualNet Developer includes support for a number of model libraries that enable you to design networks using *SNT*-developed protocol models. Purchase of QualNet Developer includes the Developer Model Library; additional libraries for modeling WiFi networks, mobile ad-hoc networks (*MANET*), military radios, *WiMAX*, and cellular models are also available. Refer to the QualNet Model Libraries data sheet for more information or check the products page on our website. Source code for the purchased libraries is included with your installation.

3.7 QualNet Developer Graphical User Interface (GUI)

Scenario Designer is a network design tool that allows you to set up terrain, network connections, subnets, mobility patterns of wireless users, and other functional parameters of network nodes. Using intuitive, click and drag, operations you can also customize the entire protocol stack of one or a group of nodes. You can also specify the application layer traffic and services that run on the network.

Animator offers in-depth visualization and analysis of a network scenario designed in Scenario Designer. As a simulation is running, users can watch packets at various layers flow through the network and view dynamic graphs of critical performance metrics. You can also assign jobs to run in batch mode on a faster server and view the animation data on a remote computer. You can perform “what-if” analysis by setting a range of values for a particular protocol parameter and comparing the network performance results for each of them.

3D Visualizer is a tool for advanced visualization of network scenarios and simulations. It is used for visualizing network topology, communication events, and statistics in 2D and 3D space.

Analyzer is a statistical graphing tool that displays hundreds of metrics collected during simulation of a network scenario. You can choose to see pre-designed reports or customize graphs with their own statistics. Multi-experiment reports are also available. All statistics are exportable to spreadsheets in *CSV* format.

Packet Tracer is a packet-level visualization tool for viewing the contents of a packet as it goes up and down the network stack.

3.8 QualNet Developer Command Line Interface

The QualNet command line interface enables a user to run QualNet from a *DOS* prompt (in Windows) or from a command window (in *UNIX*). When QualNet is run from the command line, input to QualNet is in the form of text files which can be created and modified using any text editor. Building and running scenarios with the command line interface takes less memory and scenarios typically run faster than with the *GUI*. With the command line interface the users have the flexibility to interface with visualization and analysis tools of their choice.

3.9 QualNet External Interfaces

QualNet Developer can also interact with a number of external tools in real-time. Two of these are:

- IPNE module, part of the Network Emulation Interface Library, allows virtual nodes in a QualNet Developer scenario to interact with real-world networks. This hardware/system in the loop capability allows real-device application traffic to undergo 'network effects' as it passes through the wired and wireless network modeled inside of QualNet.
- *HLA/DIS* module, part of the Standard Interfaces Library, allows QualNet Developer to interact with other *HLA/DIS* compliant simulators and computer-generated force (*CGF)* tools like *OTB.*

3.10 Scenario-based Network Simulation

- In QualNet Developer, a specific network topology is referred to as a scenario. A scenario allows the user to specify all the network components and conditions under which the network will operate. This includes: terrain details, channel propagation effects including path loss, fading, and shadowing, wired and wireless subnets, network devices such as switches, hubs and routers, the entire protocol stack of a variety of standard or user-configured network components, and applications running on the network. Most of these are optional; you can start with a basic network scenario and specify as much detail as necessary to improve the accuracy of your network model.

3.10.1 General Approach

- In general, a simulation study includes three phases. The first phase is to create and prepare the simulation scenario based on the system description and metrics of interest. The second phase is to execute the created scenario and collect simulation results. Simulation results can include scenario animations, runtime statistics, final statistics, and output traces. The last phase is to analyze the simulation results. Typically, users may need to adjust the scenarios based on the observations from the second and third phases. This general procedure is illustrated in Figure 10.

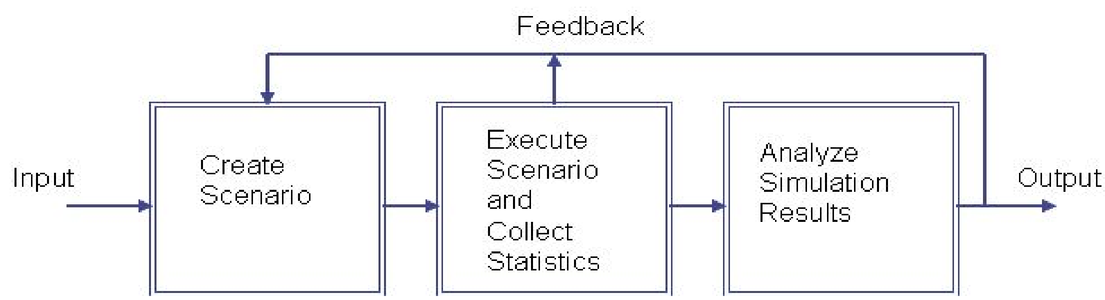

Figure 10: Scenario-based Simulation

3.10.2 Creating Scenarios

Creating a scenario can be divided into several steps focusing on different aspects. The key steps in creating a simulation scenario for QualNet are illustrated in Figure 11. The general approach is to first configure the general properties which are applicable to the whole scenario. Next, specify the network topology by creating subnets, placing nodes, and defining node mobility. Then one needs to configure the protocol stack for individual nodes or groups of nodes as necessary. The last step is to configure parameters for collecting simulation results and controlling runtime performance.

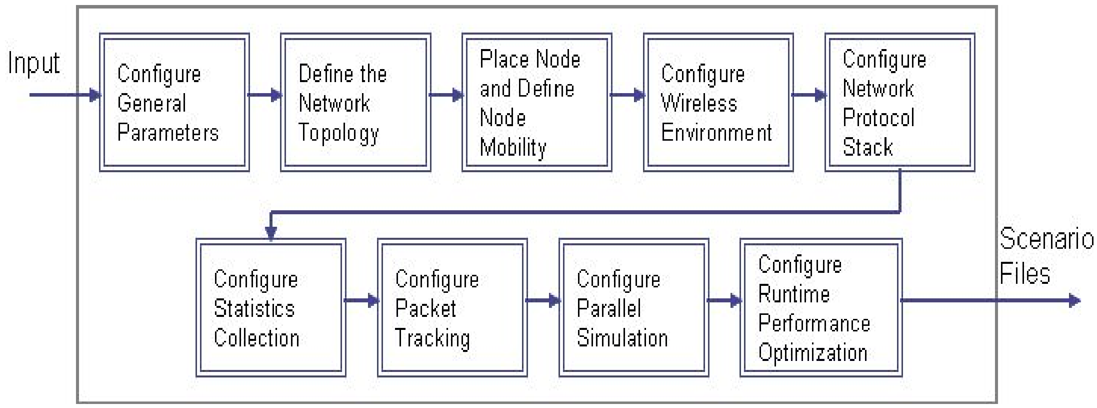

Figure 11: Creating a Scenario

3.10.3 Files Associated with a Scenario

Input to the QualNet simulator consists of several files. For the command line interface, the input files are text files. The main input files for command line are:

- **Scenario configuration file:** This is the primary input file for QualNet and specifies the network scenario and parameters for the simulation. This file usually has the extension ".config".
- **Node placement file:** This file is referenced by the scenario configuration file and specifies the initial position of nodes in the scenario. (The node placement file may also contain the future positions of nodes.) This file usually has the extension ".nodes".
- **Application configuration file:** This file is referenced by the scenario configuration file and specifies the applications running on the nodes in the scenario. This file usually has the extension ".app".

In addition to the above three files, QualNet may use other input files. These additional files depend upon the models specified in the configuration file and are referenced by the configuration file. These input files are text files which can be created using any text editor. When using the command line interface, the user has to create these files manually.

When the user creates a scenario in QualNet Scenario Designer, a scenario description file (with the extension ".scn") is created. The major input files representing the scenario

(scenario configuration, node placement, and application configuration files) are automatically created by QualNet Scenario Designer.

The primary output file generated by a QualNet simulation run is a statistics file, which has the extension ".stat". This file contains the statistics collected during the simulation run. Other output files that may be generated by QualNet include the trace file (which has the extension ".trace") which records packet traces, and the animation file (which has the extension ".anim") which records the animation trace of a scenario when the scenario is run in QualNet Animator or QualNet 3D Visualizer.

Both the statistics and trace files are text files which can be viewed using any text editor. In addition, QualNet Analyzer can be used to view the contents of the statistics file in a graphical, easy to analyze manner. Similarly, QualNet Packet Tracer can be used to view the contents of the trace file graphically.

CHAPTER 4 - PROPOSED ALGORITHM AND SIMULATIONS

4.1 Backoff Algorithm and Contention Window management scheme

In IEEE802.11 Wireless LAN when a collision occurs, there is the need of a backoff time, which is randomly selected from the Contention Window (*CW*). The commonly used backoff algorithm is Binary Exponential Backoff Algorithm (*BEB*). In *BEB* algorithm, the value of the *CW* is doubled every time a node experiences an unsuccessful transmission. If there is a successful transmission, *CW* is reset to minimum value. We have proposed an algorithm in which we have modified the procedure of increasing the CW in case of transmission failure occurs in order to decrease the average end to end delay and average jitter. There are two modules in the proposed algorithm, which are explained below.

4.1.1 Description of Module 1

The manner in which contention window vary depends on the traffic category. When collision occurs, for high priority traffic the contention window varies linearly till it reaches certain value after which it increases at faster rate whereas the contention window with lower priority traffic increases at faster rate.

Whenever there is unsuccessful transmission occurs first of all *AC* of the traffic flow will be checked. If it is high priority traffic i.e. video or voice then its current value of its *CW* will be checked, if this value is less than twice of its *CWmin*, then its *CW* is incremented linearly till it reaches twice the *CWmin*. Beyond the twice of *CWmin* value is increased by multiplying with the factor of 1.5. For the low priority traffic *CW* value is increased consistently by multiplying with the factor of 1.5.

Increase Contention Window Function:

Begin:

If (AC>=2)   //for video and voice traffic

If (CW[AC] < 2×CWmin[AC])

CW[AC] = MIN (CW[AC]+1, 2×CWmin[AC])

Else

CW[AC] = MIN (CW[AC] ×1.5, CWmax[AC])

Endif

Elseif (AC >=0 and AC < 2) //for Best effort and background traffic

CW[AC]=MIN (CW[AC] ×1.5, CWmax[AC])

Endif

where AC is the Access Category.

4.2 Description of Module 2:

Another modification we have done in our algorithm is changing parameters of AIFS according to the priority of Traffic Category. In case of *EDCA* the value of *AIFS* parameter for every Access category is chosen in same way as given below:

AIFS=SIFS+AIFSN×SLOTTIME

In order to provide the priority to higher traffic categories we have modified the *AIFS* by lowering the AIFS value for Traffic categories 2 and 3. *AIFS* value for Traffic category 2 and 3 has been reduced to *SIFS* only. Whereas *AIFS* value calculation function for Traffic categories 0 and 1 are same as original *EDCA* function. By using algorithm the *AIFS* value has been decreased for Access categories having high priority. This leads to reduce Average End to End Delay and Average Jitter significantly.

AIFS Calculation Functions

If (AC>=2) //for voice or video traffic

AIFS=SIFS;

Else (AC >= 0 and AC <2) //for Best effort and background traffic

AIFS=SIFS + AIFSN × SLOTTIME

Endif

4.3 Simulations and Results

To show the effectiveness of the proposed algorithm, we have simulated experiments by implementing wireless networks under *EDCA* and Proposed method. All the simulations have been done by using Qualnet network simulator designed by scalable networks.

4.3.1 Experiment 1:

In this experiment, we have 6 nodes in 1000 × 1000 areas, which are configured under 802.11e Ad-Hoc wireless network. A Random Distribution model has been followed. Nodes are fully independent i.e. without any Access Point to coordinate the channel access and are operating in a distributed environment. Constant bit rate connections have been used between every node. For best effort traffic 64 byte packets are sent at an interval of 20 milliseconds by giving data rate of 25.6 Kbps. For the voice traffic 512 byte data packets are sent at an interval of 16 milliseconds giving data rate of 256 Kbps. Figure 13 shows the properties of best effort traffic CBR. For both traffics number of packets increased from 100 to 2500 and the simulation has been done. Finally graphs for average Jitter, Average End to End delay, and Average Throughput in presence of both low priority and high priority traffic have been plotted against the number of packets sent. Performance of the proposed modification can be compared by existing *EDCA* with the help of the graphs. Detailed properties of scenario are given in table 4.

Table 4: Properties of scenario 1

Property	Value
Terrain Size	1000 × 1000
Simulation Time	30s
Number of Nodes	6
Item Size	512 bytes having priority 7 and 64 bytes having priority 0
CBR Applications having priority 7	1→6, 6→7, 3→5, 4→2
CBR Applications having priority 0	6→1, 1→3, 4→5, 6→2

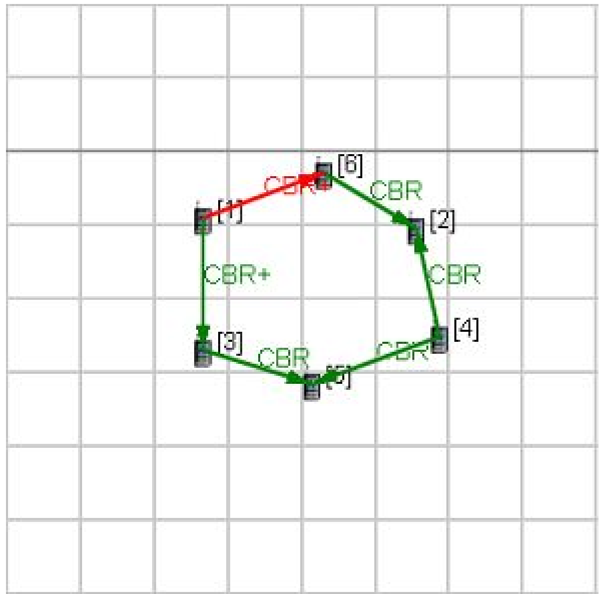

Figure 12: Scenario 1 screen shot

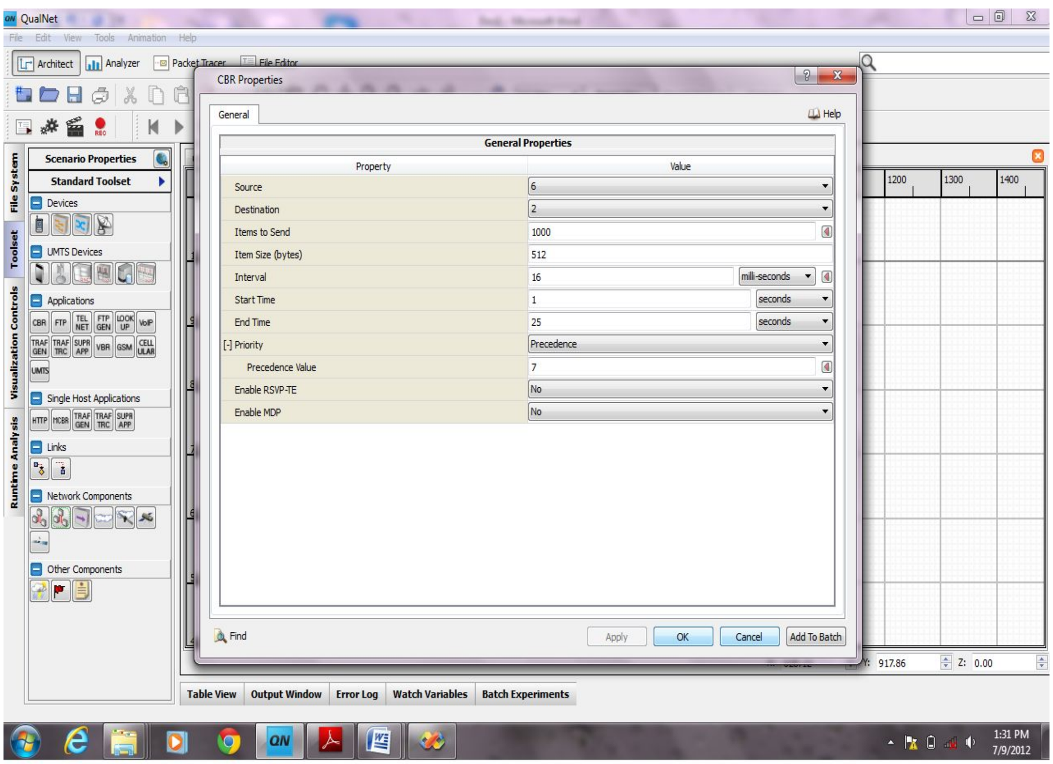

Figure 13: Snap shot of properties of CBR links

4.3.2 Results

The above scenario described in Figure 12 was run successfully. We have simulated the experiment firstly for 100 packets and then 500 till 2500 packets. The experiments were performed once for existing *EDCA* model then for proposed method. Then *QoS* parameters are compared of both experiments.

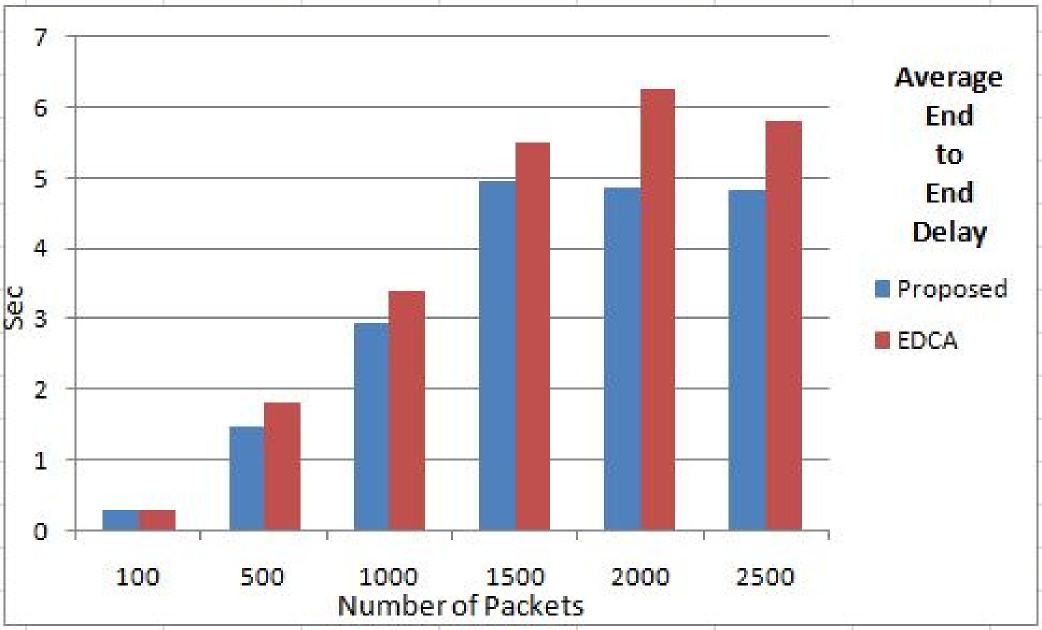

Figure 14: Average End to End Delay for 6 nodes

Graph of Figure 14, shows that our proposed method provides lower Average End to End Delay as compared to conventional *EDCA* method. Firstly for 100 packets the performance of both methods is similar. With increment in number of packets, the performance of *EDCA* degrades as compared to proposed method.

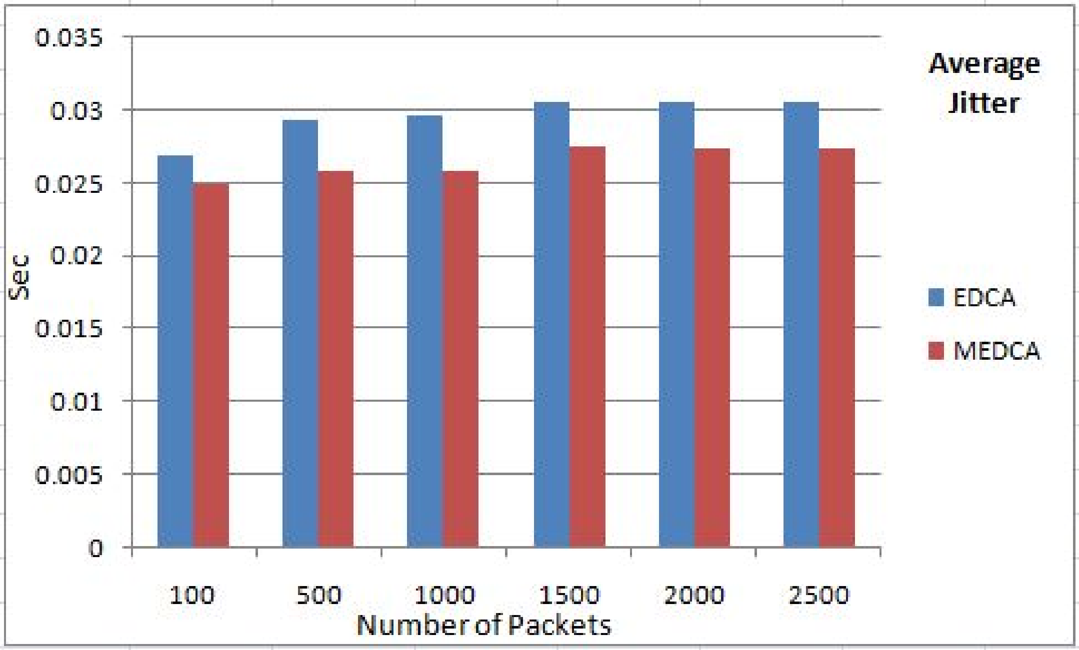

Figure 15: Average Jitter for 6 nodes

Above graph in fig 15, shows that our proposed method provides lower Average Jitter of as compared to conventional *EDCA* method. Average Jitter of the network shows a steady improvement for any no. of packets when proposed algorithm is applied. Jitter indicates the variation in delay experienced in network.

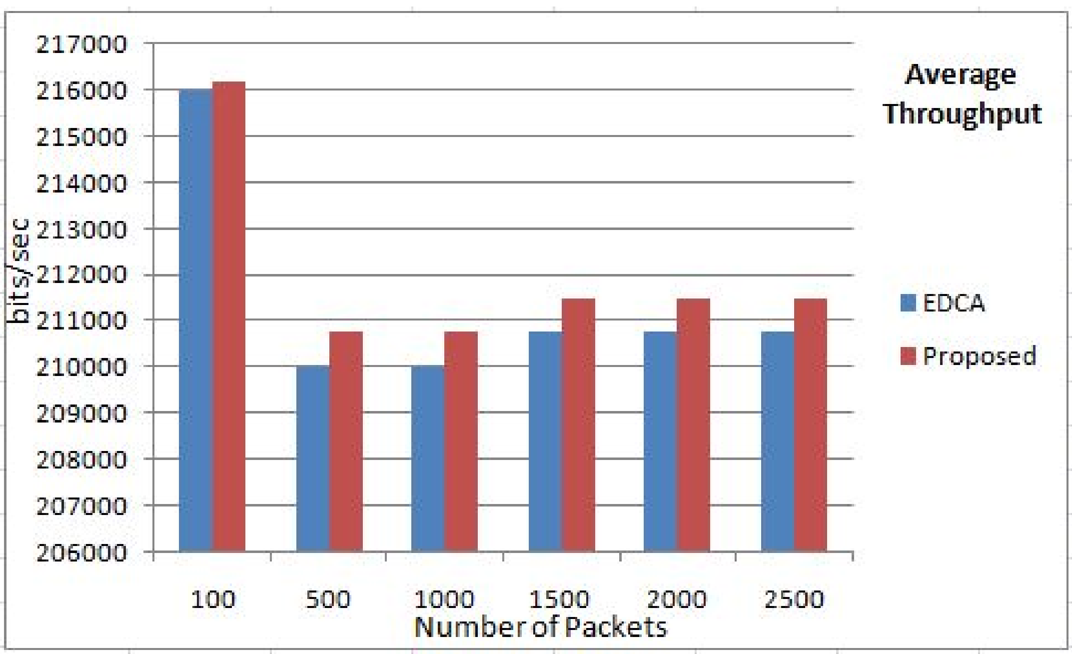

Figure 16: Average Throughput for 6 nodes

In Figure 16, graph shows that our proposed method gives a better throughput performance.

4.3.3 Experiment 2

Second experiment is performed with increasing the number of nodes in network and number of packets. In this scenario simulation is carried with 30 nodes on 1000 x 1000 area. Again a random distribution model has been chosen with fully independent nodes. Nodes are operating in an AD-Hoc mode without a central access point. Constant bit rate connections have been used between nodes. For best effort traffic 64 byte packets are sent at an interval of 20 milliseconds by giving data rate of 25.6 Kbps. For the voice traffic 512 byte data packets are sent at an interval of 16 milliseconds giving data rate of 256 Kbps. Now in this simulation number of packets increased from 1000 to 5000 for both traffics.

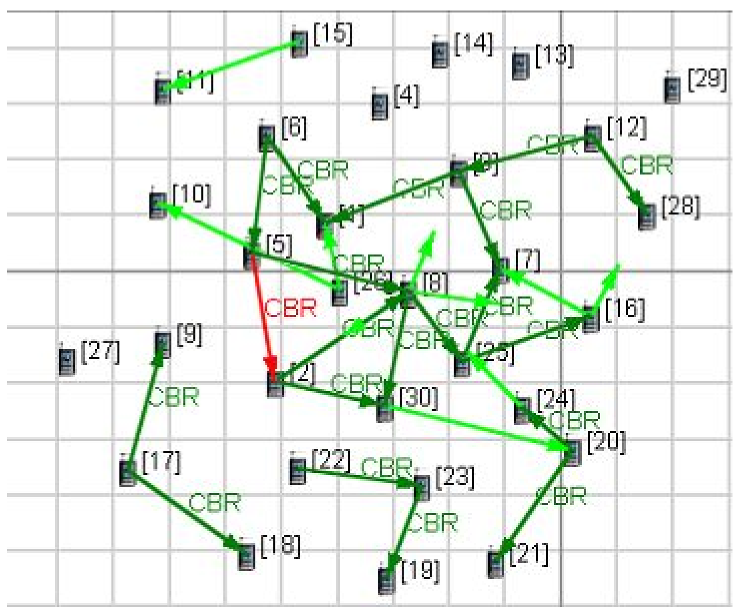

Figure 17: Snap shot of scenario 2

Node placement scenario with 30 nodes configured in 802.11e Wireless Ad-Hoc Network is shown in Figure 17. Properties for scenario 2 are as described in table 5 given below.

Table 5: Properties for scenario 2

Property	Value
Terrain Size	1000 × 1000

Simulation Time	30s
Number of Nodes	30
Item Size	512 bytes having priority 7 and 64 bytes having priority 0
CBR Applications having priority 7	6→5, 3→1, 12→28, 5→28, 2→30, 25→16, 8→3, 17→9, 23→19, 20→21
CBR Applications having priority 0	6→1, 3→7, 12→3, 5→2, 2→8, 25→27, 8→25, 17→18, 22→23, 20→24

4.3.4 Results

These Graphs given in Figure 18, 19, 20 shows the impact on Quality of Service parameters Average End to End Delay, Average Jitter and Average Throughput of proposed algorithm in comparison with conventional *EDCA* algorithm.

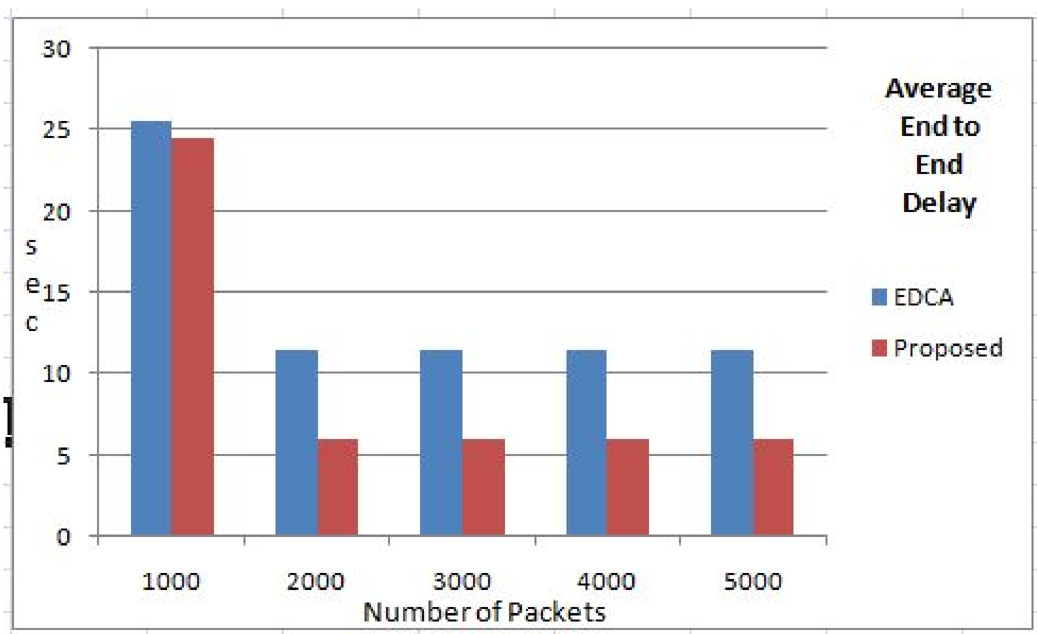

Figure 18: Average End to End Delay *EDCA* and proposed method

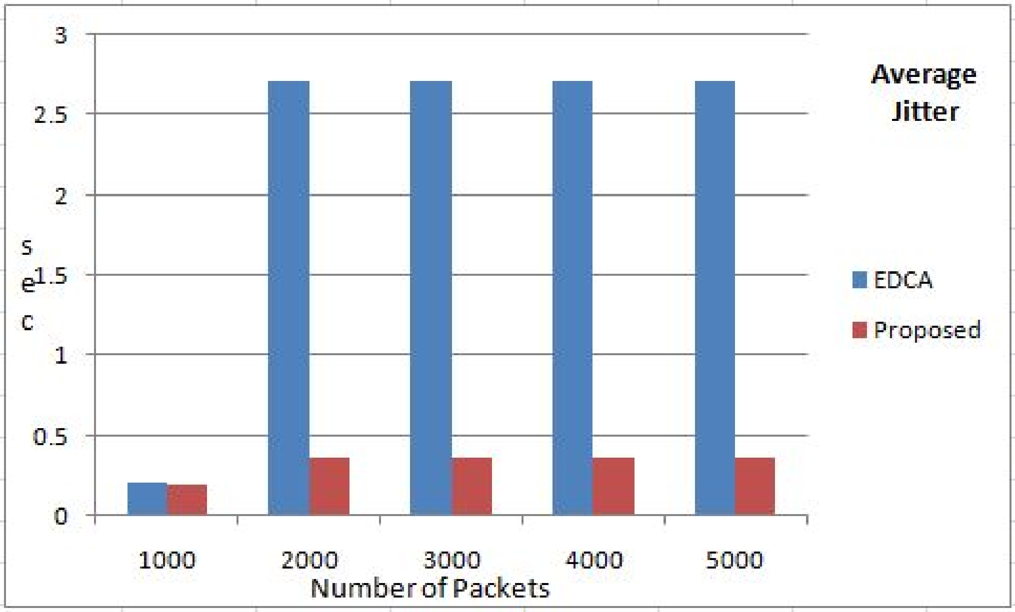

Figure 19: Average jitter performance of *EDCA* and proposed method

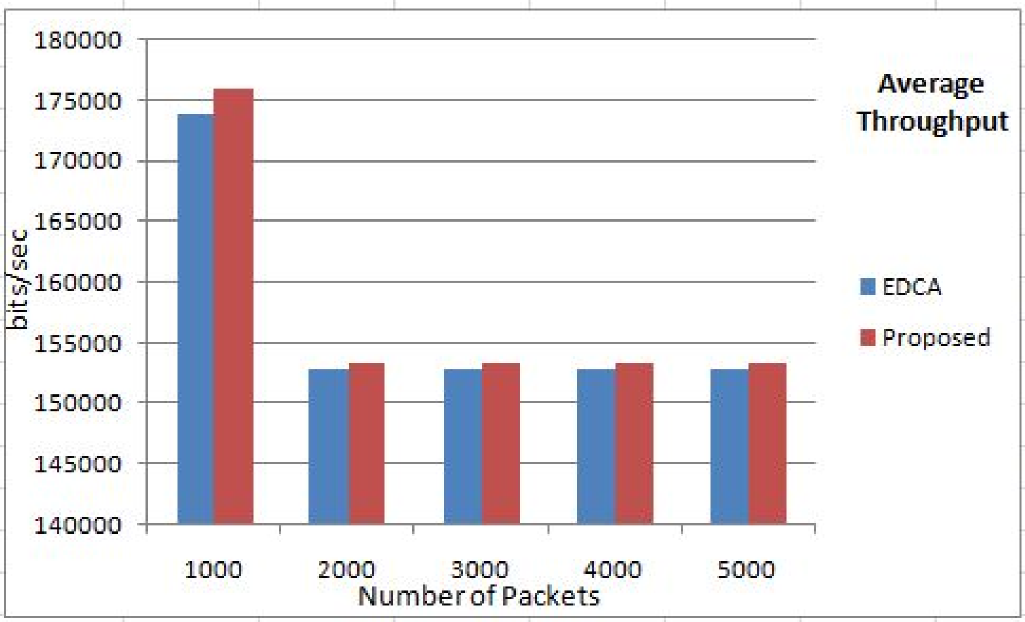

Figure 20: Average throughput analysis of *EDCA* and proposed method

CHAPTER 5 - CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

In this thesis we have studied an overview over the existing IEEE 802.11 Wireless *LAN MAC* and its problems of achieving a sufficient Quality of Service in case of time bounded data like Video and VoIP. This thesis explains IEEE standard 802.11e basic working and its functionality in detail. We have further proposed enhancement in IEEE 802.11e with its medium Access Function *EDCA* by varying the Contention Window of high priority traffic. Modification has implemented in increase Contention Window function in case of transmission failure due to collision on network. In addition I have modified *AIFS* calculation function for high priority traffic categories. This function provides priority to transmit Voice and Video data over network for than Best Effort Traffic Category data. We have chosen Qualnet network Simulator 5.2 version to carry out this simulation. In simulation we have consider Average Jitter, Average End to End Delay and Average Throughput in our main focus. Then we have compared results of proposed algorithm with existing *EDCA* algorithm. The results of the simulation have been added in this thesis from where we can conclude that proposed algorithm for increasing Contention Window and modified *AIFS* calculation function gives better performance than existing *EDCA* method.

Simulation has performed on two different scenarios: one for 6 number of nodes and 100 to 2500 number of packets. Second includes 30 number of nodes and 1000 to 5000 number of packets. Performance of both experiments have been analysed in respect of Average Jitter, Average End to End Delay and Average Throughput of the network.

5.2 Future work

The contention Window and *AIFSN* variation schemes have a strong impact on the performance of the Network and providing *QoS* for particular class of traffic. Proposed scheme for varying the *CW* results in improvement of parameters such as Average Jitter, Average End to End Delay and Average Throughput. Further study may be done to improve performance on the network. Average throughput parameter can be considered for further improvement. The impact of the network may be studied and mathematical analysis may be done to determine the optimal factors. It will be interesting to see where the research will take in this area in the future.

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