UNIVERSITY OF ALBERTA

Department Of Electrical and Computer Engineering

Capstone Project

MINT 709

ACI-EDCA - Hybrid Mechanism to provide QoS to Multimedia traffic in WLANS

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1.0 Introduction:

The increased demand in the market for mobility and flexibility in our everyday life has lead to the advancement from Wired LANS to Wireless LANS. The Wireless local area networks (WLANs) has received a huge boost in recent times due to advancements in portable devices such as PDAs, cellular phones, laptops, tablets. Applications range from voice over IP (VoIP), audio-conferences, video-conferences, audio on demand, and video on demand (VoD) to data applications such as text chat, web downloading, shared white-boards, etc. In todays time WLANS are available in office, home, airport and restaurants even while travelling in buses or trains.

WLANs have become an important connectivity solution for a broad range of business needs. The wireless market is expanding rapidly and hence the corresponding profit. WLANs made its remarkable footage in the manufacturing industries, healthcare, educational and research institutions and corporate offices. Current business strategies have totally changed. There is increased mobile work force environment culture has become vital in the organizations due to lack of space in office. Employees equipped with portable notebooks and make them to work flexibly from home, which is beneficial to employees and organizations in means of productivity and saving their time in travelling. It makes possible for an employee to work in teams which crossing the geographical borders. WLANs improve the productivity of the organization and lay the path to set up cost effective network setup within the organization. IEEE recognized the important role of WLANs in telecommunication industries accredited IEEE 802.11 as a standard for WLANs.

1.0.1 Quality of Service and its importance in telecommunication industry:

Now a days we are in need of reliable network performance that has become vital factor in telecommunication industries. Reliable in the sense minimal lose of packets, minimal delay and maintaining the bandwidth of the transmitted signal. Providing better QoS guarantees is become vital objective and demand in the design of future wireless industries. Quality of Service (QoS) aims at providing better networking services over current technologies like WLANS, ATMS. The Internet, which we are using, offers best-effort model since we don't know when will be the packets reach the destination. It also doesn't differentiate between network streams. These applications require quality of service (QoS) guarantees on bandwidth, delay, jitter, and loss rate. On one side, multimedia applications are sensitive to delay and jitter, though they tolerate a certain amount of losses. On the other side, data applications tolerate delay, jitter and they adapt to the available bandwidth, but they generally do not tolerate losses.

2.0 Project Description:

2.0.1 Issues faced in implementing QoS:

The IEEE 802.11 standard has become a widely used standard for WLANs. IEEE standard provides two medium access mechanisms in implementing QoS are Distributed coordinated function (DCF) and Point coordination function (PCF). DCF provides only a best-effort service and does not provide any QoS mechanism While PCF is designed to provide QoS to traffic with high priority. But this mechanism won't support QoS for high data rate multimedia applications. It incurs reasonable amount of packet loss during packet switching. So we need to go for some advanced method in order to improve the QoS.

2.0.2 Objective:

* To propose the new hybrid scheme to provide QoS to different classes of traffic in IEEE 802.11e in order provide better QoS performance results.
* To show the results by means performance graphs done by comparing the proposed scheme results with existing systems through simulation done by Network simulator (NS2) which is open source driven simulator used in research of networking experiments.

2.0.3 Project Scope:

The IEEE 802.11e standard is a scheme to afford QoS based on the demand of specific type of application. It provides differentiation of prioritized traffic on the enhanced distributed channel access (EDCA) mode, while in the hybrid coordinated channel access (HCCA) mode, it guarantees service for applications with strict QoS requirements. As EDCA is a distributed mechanism it is the most preferred operation mode that we are opting in IEEE 802.11e.

Here we put forward a hybrid scheme to provide QoS to different classes of traffic in IEEE 802.11e which is named as ACI-EDCA, since it incorporate two adaptive schemes. It works on the basis of the individual perception of a station on the state of the transmission medium, the competing conditions in the WLAN, and the throughput per access category. We perform the performance charts by simulation with the NS-2 network simulator, in which ACI- EDCA mechanism overcomes the disadvantages of previously used mechanisms and gives better performance throughput. This idea showcases an exceptional performance as it take count of the individual information about the state of the medium of each station at the same time with challenging conditions within the WLAN.

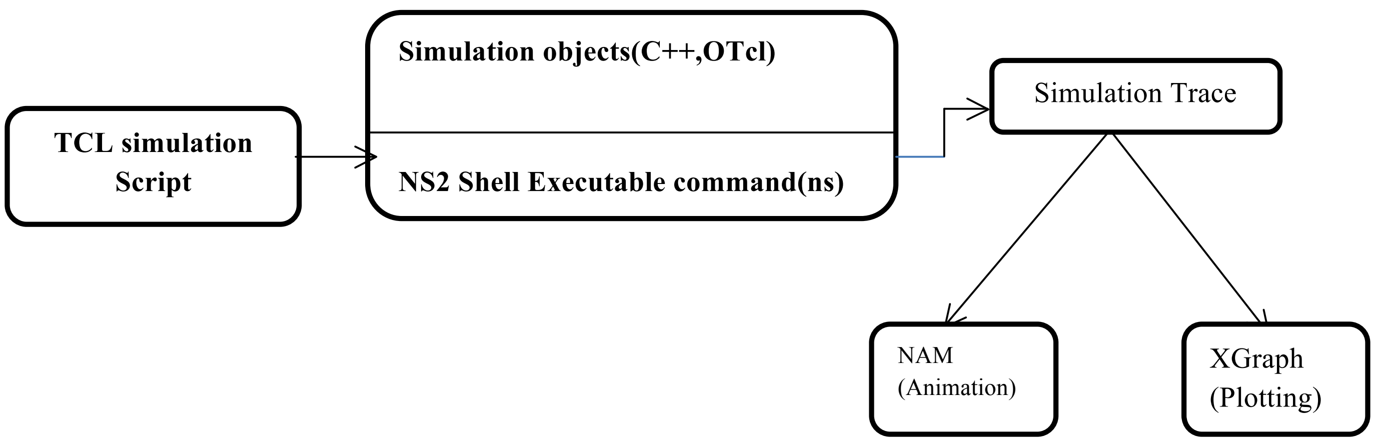
3.0 Network Simulator (NS2)

3.0.1 Description:

Network simulator (Version 2) shortly named as NS2 is most commonly used event-driven simulator tool which is very useful in analyzing the nature of telecommunication network parameters. It can work for both wired and wireless network functions and protocols like routing algorithms, TCP, UDP. It is possible in NS2 for the user to design the specific way to work for protocols and users can simulate their corresponding behaviors. Due to flexibility and simple nature, NS2 has been used commonly among networking research groups. There was further advancement made in the simulator tool in order to cope up with latest technologies.

3.0.2 Basic Architecture:

The basic architecture shown below which depicts how NS2 works.



As depicted in the architecture model, NS2 users providing the input argument as TCL simulation scripting file to the NS2 executable command (ns). With the help of two key simulation objects C++ and OTcl, we can create the simulation trace. With that trace we can plot the graph or animation to show our results. They both together called as TclCL. C++ defines the internal mechanism of simulation objects (backend operations) while OTcl set up simulation by assembling and configuring the objects and for scheduling the discrete events (Front end). OTcl acts in the front end by interacting with users and other OTcl objects. It has own procedures and variables to simplify the interaction with users and provides inbuilt C++ objects. We can set up the simulation by using the inbuilt functions but sometimes-advanced developers need something more than the in built functions. They can develop their own C++ objects and simulate the trace, as they need. Once the simulation is done we can interpret the results graphically and interactively by using NAM (Network AniMator) and XGraph.

3.0.3 Installation:

As We know NS2 in open source simulation tool which can be downloaded from internet. It runs on various operating systems like Unix, Windows and Mac. Since it is development in Unix platform, it is advisable and easier to work in Unix compared to other operating systems. NS2 source code available in two forms as a) The All-in-one suite b) Component wise. In All-in-one suite we will get all major required components and we can add optional components. No need to install components separately that is time consuming process. So as a beginner, it is preferred to install all-in-one suite.

The all-in-one suite is installed in the Unix based system by just running the install script and follows the other instructions mentioned. We need to make sure that PC should be installed with C++ compiler. The command ./install is used to install the NS2 suite in Unix systems. After installing we can verify the installation by using this command ./validate. This will run some preloaded working scripts in order to test the basic functionalities need for the users.

3.0.4 Steps involved in NS2 simulation:

There are three key steps involved in NS2 simulation:

* Simulation Design.
* Configuring and Running simulation.
* Post simulation process.

3.0.4.a Simulation Design:

The first step in simulating the network is to design the simulation. In this phase, users need to determine the purpose of simulation, network configuration and assumptions, performance measures and expected results.

3.0.4.b Configuring and Running Simulation:

This step consists of two phases.

Network Configuring Phase: In this phase users need to create the network components like node, TCP and UDP. Then we need to configure the components as per the network design.

Simulation Phase: Here the configuration the user configured in previous step will be executed. It maintains the simulation and executes the events step-by-step order. The execution stops once the clock reached the threshold value mentioned in Network configuration phase.

3.0.4.cPost Simulation Process : In this phase, it will verify the integrity of the configuration and evaluate the performance of simulated network.

3.0.5 Installation of NS2 in Linux (Fedora 8) :

In my current simulation step, I choose fedora 8 OS which is based on Linux Kernel. It is free and open source license where we can download the ISO image easily from Internet. I installed fedora 8 in VMware player.

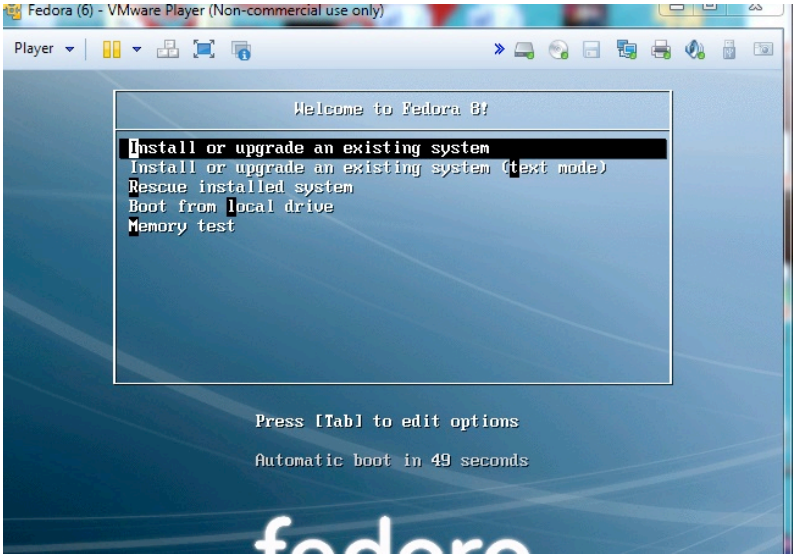


Fig1: Installing Fedora in VMware player

Fig 2: Successful installation of Fedora in VMware player.

Once the installation is done give proper user name and password and downloads the repositories successfully.

Steps involved in installing NS2:

Once the installation is done then next step is installing NS2 in Fedora. First of all download the setup file from open source (http://sourceforge.net/projects/nsnam/) and save it in desktop.

Make sure that your PC is connected to Internet. Next we need to download and install dependencies. In order to get dependencies we use YUM command which downloads and install dependencies from repositories. We have to login as root user in order to install or make changes in Linux environment. Use "SU" in the terminal and enter the root password and then you can continue the installation. I followed the procedure mentioned in this link while installing NS2 in Fedora (http://www.scribd.com/doc/32966452/NS-2-Installation-Manual)

```
lokeshk@localhost:/home/lokeshk
File  Edit  View  Terminal  Tabs  Help
You need to be root to perform this command.
[lokeshk@localhost ~]$ su
Password:
su: incorrect password
[lokeshk@localhost ~]$ su
Password:
[root@localhost lokeshk]# yum install autoconf
Setting up Install Process
Parsing package install arguments
Package autoconf - 2.61-9.fc8.noarch is already installed.
Nothing to do
[root@localhost lokeshk]# yum install gcc-c++
Setting up Install Process
Parsing package install arguments
Package gcc-c++ - 4.1.2-33.i386 is already installed.
Nothing to do
[root@localhost lokeshk]# yum install libX11-devel

Setting up Install Process
Parsing package install arguments
Package libX11-devel - 1.1.3-4.fc8.i386 is already installed.
Nothing to do
[root@localhost lokeshk]#
[root@localhost lokeshk]#
```

Fig 3 : Downloading dependencies -1

```
lokeshk@localhost:/home/lokeshk
File  Edit  View  Terminal  Tabs  Help
Nothing to do
[root@localhost lokeshk]# yum install libX11-devel

Setting up Install Process
Parsing package install arguments
Package libX11-devel - 1.1.3-4.fc8.i386 is already installed.
Nothing to do
[root@localhost lokeshk]#
[root@localhost lokeshk]# yum install xorg-x11-proto-devel
Setting up Install Process
Parsing package install arguments
Package xorg-x11-proto-devel - 7.3-3.fc8.noarch is already installed.
Nothing to do
[root@localhost lokeshk]# yum install libXt-devel
Setting up Install Process
Parsing package install arguments
Package libXt-devel - 1.0.4-3.fc8.i386 is already installed.
Nothing to do
[root@localhost lokeshk]# yum install libXmu-devel
Setting up Install Process
Parsing package install arguments
Package libXmu-devel - 1.0.3-3.fc8.i386 is already installed.
Nothing to do
```

Fig 4: Downloading dependencies -2

Since we downloaded NS2 before and kept it in Desktop now we need to untar the downloaded file .

```
[lokeshk@localhost Desktop]$ tar -xzf ns-allinone-2.35.tar.gz
[lokeshk@localhost Desktop]$ cd ns-allinone-2.35.tar.gz
bash: cd: ns-allinone-2.35.tar.gz: Not a directory
[lokeshk@localhost Desktop]$ ls
NS2 project documents.doc   ns-allinone-2.35
NS2 project documents.docx  ns-allinone-2.35.tar.gz
[lokeshk@localhost Desktop]$ cd ns-allinone-2.35
[lokeshk@localhost ns-allinone-2.35]$ ./install
```

Fig 5: Untar the NS2 file

Once you enter install it will take some time for installation. Once the installation is done perfectly we will get a message like below.

```
Ns-allinone package has been installed successfully.
Here are the installation places:
tcl8.5.10:      /home/lokeshk/Desktop/ns-allinone-2.35/{bin,include,lib}
tk8.5.10:               /home/lokeshk/Desktop/ns-allinone-2.35/{bin,include,lib}
otcl:           /home/lokeshk/Desktop/ns-allinone-2.35/otcl-1.14
tclcl:          /home/lokeshk/Desktop/ns-allinone-2.35/tclcl-1.20
ns:             /home/lokeshk/Desktop/ns-allinone-2.35/ns-2.35/ns
nam:    /home/lokeshk/Desktop/ns-allinone-2.35/nam-1.15/nam
xgraph: /home/lokeshk/Desktop/ns-allinone-2.35/xgraph-12.2
gt-itm:   /home/lokeshk/Desktop/ns-allinone-2.35/itm, edriver, sgb2alt, sgb2ns,
sgb2comns, sgb2hierns

-------------------------------------------------------------------------------
--

Please put /home/lokeshk/Desktop/ns-allinone-2.35/bin:/home/lokeshk/Desktop/ns-a
llinone-2.35/tcl8.5.10/unix:/home/lokeshk/Desktop/ns-allinone-2.35/tk8.5.10/unix
into your PATH environment; so that you'll be able to run itm/tclsh/wish/xgraph.
```

Fig 6: Installation of NS2 -1

Next we need to register the variables in order to make NS2 work. It will create link between all executable created by NS2. TCL scripts call these executable. This step is important in order to make NS2 work smoothly in the environment. Type gedit~/.bashrc in terminal which will open up the bashrc file and we can edit the file like below

```
*.bashrc
        . /etc/bashrc
fi

# User specific aliases and functions
# LD_LIBRARY_PATH
OTCL_LIB=/home/lokesh/Desktop/ns-allinone-2.35/otcl-1.13
NS2_LIB=/home/user/ns-allinone-2.35/lib
X11_LIB=/usr/X11R6/lib
USR_LOCAL_LIB=/home/user/lib
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$OTCL_LIB:$NS2_LIB:$X11_LIB:$USR_LOCAL_LIB
# TCL_LIBRARY
TCL_LIB=/home/lokesh/Desktop/ns-allinone-2.35/tcl8.4.14/library
USR_LIB=/usr/lib
export TCL_LIBRARY=$TCL_LIB:$USR_LIB


# PATH
XGRAPH=/home/lokesh/Desktop/ns-allinone-2.35 bin: /home/lokesh/Desktop/ns-allinone-2.35/
tcl8.4.14/unix:/home/lokesh/Desktop/ns-allinone-2.35/tk8.4.14/unix
```

Fig 7: Editing in bashrc file

Once the changes are made, save the file with the command source~/.bashrc

```
.bashrc
        . /etc/bashrc
fi

# User specific aliases and functions
# LD_LIBRARY_PATH
OTCL_LIB=/home/lokeshk/Desktop/ns-allinone-2.35/otcl-1.13
NS2_LIB=/home/lokeshk/Desktop/ns-allinone-2.35/lib
X11_LIB=/usr/X11R6/lib
USR_LOCAL_LIB=/home/user/lib
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$OTCL_LIB:$NS2_LIB:$X11_LIB:$USR_LOCAL_LIB
# TCL_LIBRARY
TCL_LIB=/home/lokeshk/Desktop/ns-allinone-2.35/tcl8.4.14/library
USR_LIB=/usr/lib
export TCL_LIBRARY=$TCL_LIB:$USR_LIB


# PATH
XGRAPH=/home/lokeshk/Desktop/ns-allinone-2.35 bin:/home/lokeshk/Desktop/ns-allinone-2.35/
tcl8.4.14/unix:/home/lokeshk/Desktop/ns-allinone-2.35/tk8.4.14/unix
```

Fig 8: Saving the bashrc file

After saving the document, we can make sure that everything is installed properly by using ./validate command in terminal which is not necessary step since it takes very long time but it will completely validates the functionality. Once everything is done in order to make sure that NS-2 working type ns in terminal, we will get % sign on the terminal screen like below

```
[lokeshk@localhost etc]$ gedit ~/.bashrc
[lokeshk@localhost etc]$ source ~/.bashrc
[lokeshk@localhost etc]$ ns
%
```

Fig 9: Successful installation of NS2

4.0 Development of QoS in IEEE standards:

In current scenarios, Wi-Fi networks based on the IEEE 802.11 standard are commonly used technologies to acquire wireless broadband Internet access. Almost all mobile devices like laptops, smartphones and tablets have in built Wi-Fi transceivers. Previously, Wi-Fi used as the cordless substitute for Ethernet and only used for transmission of non-real-time traffic like email, file sharing with acceptable quality. Due to the evolution of Internet applications, the real-time traffic applications like VoIP, video conference calls, online gaming and online streaming which going to occupy more than half of all Internet traffic in future. This real-time multimedia traffic application strictly demand higher Quality of Service (QoS) requirements which includes low and stable end-to-end delay, low packet loss probability, and minimal throughput. However, such QoS support was not incorporated in the original IEEE 802.11standard(1999).

Telecom experts realize the importance of QoS in WLANs and put huge effort to improve QoS support in 802.11. The remarkable step in development was the 802.11e amendment, which launched several mechanisms for providing QoS support in single-hop networks including two coordination functions Enhanced Distributed Channel Access (EDCA) and Hybrid Coordination Function Controlled Channel Access (HCCA). It also includes admission control mechanism. But still neither EDCA nor HCCA can provide absolute service guarantees, because EDCA is based on random contention, while HCCA lacks inter-cell coordination. Another note-worthy development is the extension of the initial single-hop paradigm to a multi-hop one is specified in the 802.11s amendment. In multi-hop networks, centralized coordination (HCCA) cannot be applied and EDCA performance is inadequate. Therefore, the problem of QoS provisioning in such networks is highly complex than in single-hop networks. This problem has not been completely solved still. The initial step towards resolving this obstacle was the launch of a new coordination function, Mesh Coordination Function Controlled Channel Access (MCCA), which allows reserving channel resources in a distributed manner. It can be used for QoS provisioning in multi-hop networks.

Later, IEEE recognized that several challenges need to be addressed for 802.11 to cope up with the rapid growth in industries and clients demands. Among the shortcomings of the IEEE 802.11 standard was the inadequacy of mechanisms for the prioritization of different Audio/Video (AV) streams that fall under the same access category (AC). If we consider a videoconference and TV broadcast which are both sent using the video AC. Since these streams have varied QoS requirements they should be served with different priorities. Moreover, the 802.11 standard did not comprise a mechanism for the reliable transmission of multicast streams. In order to overcome these issues, a new task group (802.11aa) was established to develop a set of enhancements for robust AV streaming. This standard also addresses the issue of inter-network interference that is quite common in WLANs.

After that, another issue related to management frames was detected. The number of management frame types in the IEEE 802.11 standard has been remarkably increased from its initial release to its current version. As of now all management frames are transmitted with the highest priority. This might cause interference with the transmission of multimedia traffic. So IEEE 802.11ae standard has been designed for the flexible prioritization of management frames.

5.0 IEEE 802.11 Family Specifications:

The 802.11 specifications were evolved mainly for Wireless Local Area Networks (WLANs) by the IEEE and which comprises Ethernet-based protocol standards: 802.11, 802.11a, 802.11b, 802.11g and 802.11e. Apart from that there are various other standards in 802.11 that is developed to overcome some drawbacks in the existing IEEE standards.

5.0.1 IEEE 802.11 -This standard provides MAC and PHY functionality for wireless connectivity for the devices which is fixed, portable and at moving speeds. It gives 1 or 2 Mbps transmission in the 2.4 GHz band in Frequency hopping spread spectrum (FHSS) or Direct sequence spread spectrum (DSSS). This standard is no longer used and has largely been replaced by advanced standards that invented further after that.

5.0.2 IEEE 802.11a - It is one of the physical standards for WLANs that gives maximum data rate 54-Mbps in the 5GHz band. Here eight radio channels are available. It uses OFDM encoding scheme. OFDM breaks up fast serial information signals into various slower sub-signals that are transmitted at the same time via different frequencies, which ensures much negligence to interference caused by them. It gives higher data throughput and greater number of channels that shield against interference from neighbouring access points.

5.0.3 IEEE 802.11b -It is one of the physical standards for WLANs, which gives maximum data rate 11-Mbps in the 2.4 GHz band. Here three radio channels are available. It uses DSSS scheme. Due to the limit of three radio channels it might cause interference with neighbouring access points.

5.0.4 IEEE 802.11d -This standard is additional feature to Media Access Control Layer in 802.11. It will allow access points to communicate information on acceptable channels with minimum power level. This standard is not allowed to operate in all countries. There are some restrictions in using this standard in some places.

5.0.5 IEEE 802.11e – This standard defines the Quality of Service (QoS) support for LAN applications. It is actually an enhancement to the 802.11a, 802.11 band 802.11g standards. It enhances QoS features for data, voice multimedia real-time traffic applications to the existing wireless standards.

5.0.6 IEEE 802.11f -This standard defines the registration of access points within the network and when there is a communication takes place between two access points, the user has to hand-over the information from one access point to another. It focuses on inter-operability within a multi-vendor WLAN networks.

5.0.7 IEEE 802.11g-This physical standard for WLANs which gives maximum data rate 54 Mbps in the 2.4 GHz and 5 GHz band over short distances. Here three radio channels are available. OFDM modulation scheme is implemented here. It also supports Complementary Code Keying (CCK) in order to compatible with IEEE 802.11b standard. In order to operate in faster links it supports Packet Binary Convolutional Coding (PBCC).

5.0.8 IEEE 802.11h- This standard is a addition to the MAC layer in order to fulfill with European Union standards for 5GHz LAN. As per European Union regulations, it demands that it should have Transmission Power control and Dynamic Frequency Selection. TPC regulates the power level needed during transmission and DFS selects the desirable radio channel at the access point in order to minimize the interference with other systems.

5.0.9 IEEE 802.11i - This standard is a addition to the MAC layer in order to improve the security. It can be implemented in previous standards like 802.11a,b and g. This standard uses some different encryption and authentication methods like Temporal Key Integrity Protocol (TKIP) rather than using traditional WEP. This overcomes the security threat issues in previous standards.

5.0.10 IEEE 802.11x – This standard is used to regulate the access control to client to the network by using extensible authentication methods. It is nothing but an enhancement of 802.11i standard. This one also can be implemented in previous standards like 802.11a,b and g.

5.0.11IEEE 802.11p:

This standard is used in traffic class and dynamic multicast filtering. It provides a way to differentiate the traffic in priority classes in order to support the QoS. It is the integral part of 802.11e standard. This one also can be implemented in previous standards like 802.11a,b and g.

All these standards are based on the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance), which is effective way to minimize collision and loss of packet data. There are lots of other amendments of original 802.11 standards. In 2007, Task group (TGma) combined the 8 major amendments (802.11a, b, d, e, g, h, i, j) to one single standard and renames it to IEEE 802.11-2007. It is designed in a way that it provides interoperability with networks. 802.11u allows devices such as GSM and WCDMA cellular phones to operate in a WLAN. It assumes that a user is not pre-authorized to use the network, and allows access based on the user's relationship with the network. It largely improves the connectivity of a travelling mobile station. The most significant contribution of the 802.11specification is that it allows for interoperability with different vendors equipment.

6.0 WLAN Technologies:

The different WLAN technologies which are emerged during technological advancements :

* Narrowband
* Spread spectrum
* Frequency hopping spread spectrum(FHSS)
* Direct sequence spread spectrum(DSSS)

6.0.1 Narrowband:

The name itself says that narrowband technology uses very short range of radio frequency which is in the range of 50 cps to 64 Kbps for data transmission.

6.0.2 Spread Spectrum:

This one was originally intended to use in military. Spread Spectrum technology allows for greater bandwidth by altering the frequency of the transmitted signal time to time there by spreading the transmission across multiple frequencies. It uses more bandwidth when compared to narrowband. This method of transmission is more secure and reliable but very easier to detect.

6.0.3 Frequency Hopping Spread Spectrum (FHSS)

Frequency hopping spread spectrum (FHSS) technology is a method of transmitting radio signals by rapidly changing carrier frequency among many frequency channels available using a sequence which is known to transmitter and receiver to produce a single transmission signal. FHSS operates around 79 frequencies in 2.4 GHz bandwidth. Every frequency is GFSK modulated. Its channel width is a 1MHz and data rate is up to 1Mbps to 2Mbps. Bandwidth requirement for FHSS is much greater but this is over the course of multiple carrier frequencies, which is quite negligible.

6.0.4 Direct Sequence Spread Spectrum (DSSS)

In Direct sequence spread spectrum (DSSS), stream of information that needs to be transmitted is divided into small segments across a frequency channel. At the point of transmission the data signal is combined with a higher data rate bit sequence forming a redundant bit pattern which s generally termed as Chipping code. Longer the chipping code, then the original transmitted data will be received properly in the RX end. Even though DSSS uses more bandwidth than FHSS, DSSS is more reliable and resists interference. The chipping code helps the signal to resist against interference and original data can still be recovered without retransmission of the signal even though the data bits are damaged.

7.0 Wireless LAN – 802.11 Standards:

7.0.1 MAC – Media Access Control:

MAC protocols used in design of wireless LANs using the IEEE 802.11 class of protocol suites. It is the sub-layer of data link layer that is between Logical Link Control (LLC) and Physical layer. The following assumption is made in the design of the CSMA/CD protocol in wired LAN i.e. the signal from any computer in a network could reach all computers in the network. In a wired LAN, this assumption must hold for computers to be able to reach each other and for the collision detection mechanism to work. However, in a wireless LAN, the above assumption may not hold. That is, signal from a computer may not reach all the computers in the network. Hence, at the MAC level, we do not go for collision detection. For two computers to be able to communicate, service of another computer in the network or a fixed infrastructure we use an Access Point (AP).

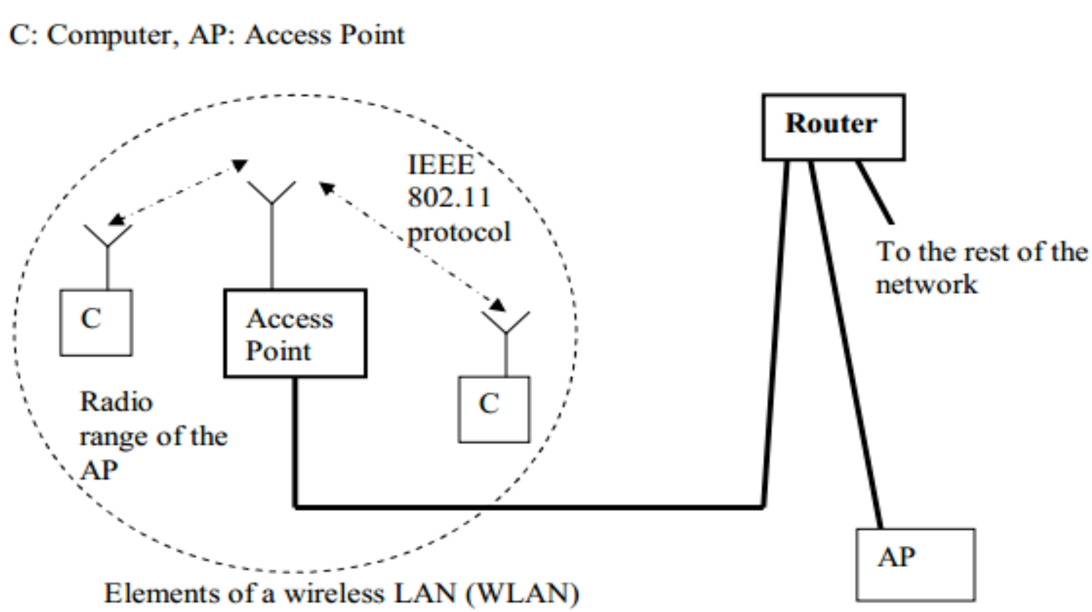


Fig 10: Elements of WLAN

A wireless LAN using an Access Point (AP) is shown in Figure 10. AP is the main part of the infrastructure to support a wireless LAN. AP is connected to a router, which in turn is connected to the rest of the network and the Internet. One of more APs may be connected to the same router as shown or different APs may be connected to different routers. The APs as well as user computers are equipped with an identical radio interface commonly known as the IEEE 802.11 standard interface. The IEEE 802.11 standard specifies both the physical and MAC layers for building a wireless LAN. The PHY layer defines the air interface between two IEEE 802.11 equipped devices and the MAC layer defines the medium access control protocols to access the shared medium.

7.0.2 802.11 – MAC Frame Format:

The MAC layer frame consists of nine fields as shown in Fig:9

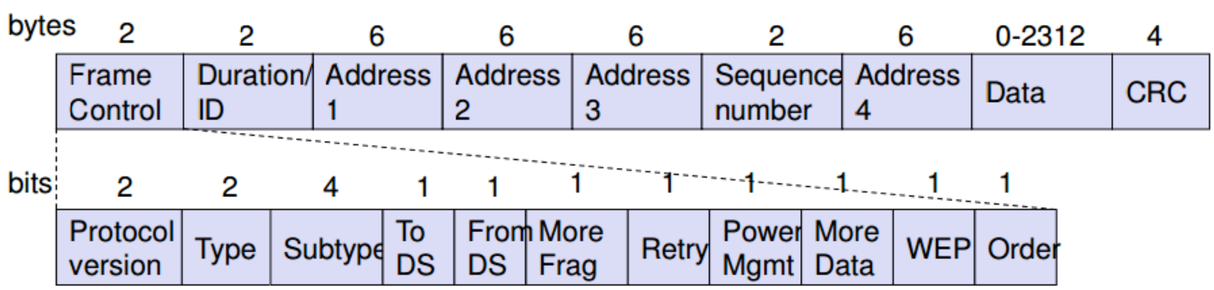


Fig 11 : Mac Frame Format

Frame Control (FC): The Frame control field is 2 bytes long and defines the type of frame and some control information.

Addresses: There are four address fields in MAC layer Frame Format. Each field is 6 bytes long. The value of address field depends on the value of from and to the destination stations (DS).

Sequence Control: This field tells about the sequence number from which is need to be used in flow control.

Frame body: This field has information that is based on type and sub type defined in Frame control field. Its value ranges from 0 to 2312 bytes.

7.0.3 Frame types:

There are three types of frames defined by IEEE 802.11.

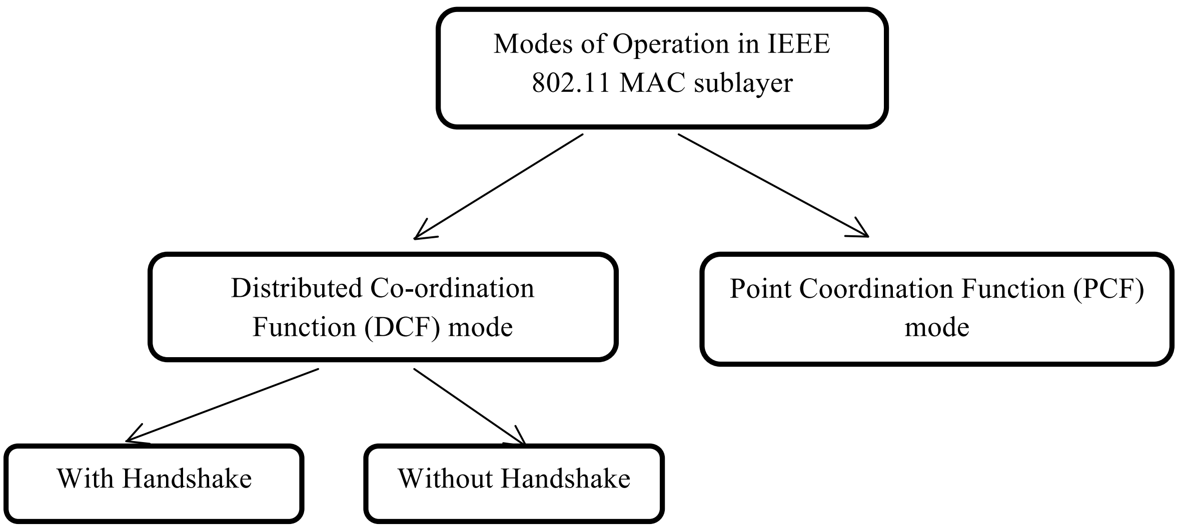
Management Frames: This frame is used for initial communication between stations and access points. It performs supervisory functions.

Control Frames: Control frames are used for channel acquisition and acknowledging if frames are received. It carrier- sensing the maintenance functions.

Data Frames: Data frames carry higher-level protocol data in its frame structure. It also carries data and control information.

7.0.4 Modes of operation of IEEE 802.11 MAC protocol:

IEEE 802.11defines two MAC sublayers. It is necessary to understand the different modes of operation of the protocol as classified below.



PCF mode of operation:

In this mode of operation, an AP acts as the central controller for all the computers lying within the radio range of the AP. The AP decides whom and when will transmit. So there will be no contention among computers for medium access. The AP can follow a round-robin policy to assign time slots to individual computers, by then guaranteeing a certain amount of bandwidth to each computer. Because of this guarantee of allocation of bandwidth, this mode of operation can support real-time traffic. But still if the amount of traffic generated by different computers widely varies, this mode is won't work for that. This is due to the fact that the AP may allocate bandwidth to a computer, which may not have much data to transmit. The implementation of the PCF mode of operation is optional.

DCF mode of operation:

In this mode of operation, the AP's presence in the medium is not necessary. Computer scan communicate among them using the DCF mode of operation without the assistance of an AP. In this case the computers have formed an ad hoc network, where there is an absence of infrastructure like APs. To construct a wireless LAN with the capability to connect to the Internet, it is essential to have an AP which is connected to a router. Because of contention among computers for medium access, there is no guarantee of bandwidth and there is no bound on message delay. Thus, the DCF mode of operation is not suitable for real-time traffic. Rather, data delivery is made on a best effort basis that is the network makes an effort to deliver data across the wireless medium, but there is no guarantee of bandwidth or bound on delay. In IEEE 802.11 implementation of the DCF mode of operation is preferred over PCF due to its centralized and contention free polling access method.

7.0.5 802.11 - MAC Layer – Inter Frame Spacing:

The three different inter framing spacing used in MAC layer are

- SIFS (Short Inter Frame Spacing) .10 us in 802.11b
  >Highest priority for ACK, CTS, polling response
- PIFS (PCF IFS) . 30 us in 802.11b
  >Medium priority for time-bounded service using PCF
- DIFS (DCF, Distributed Coordination Function IFS). 50 us in 802.11b
  >Lowest priority for asynchronous data service

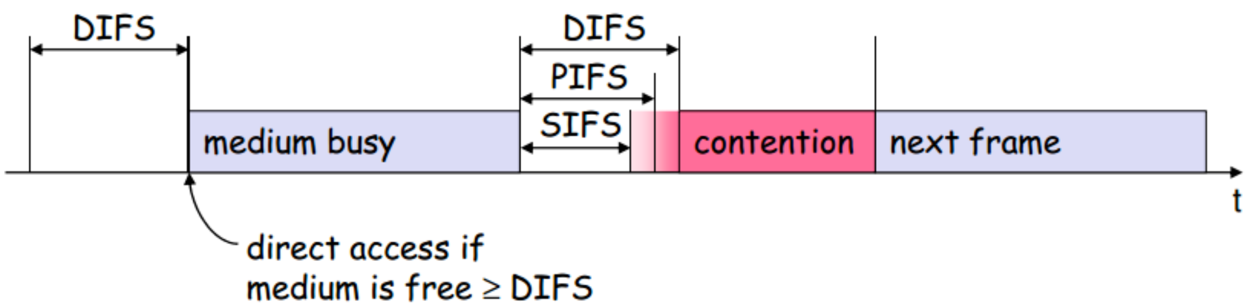


Fig 12 : Inter Frame spacing

Short interframe space (SIFS):

Short Interframe Space (SIFS), is the small time interval between the data frame and its acknowledgment. SIFS are found in IEEE 802.11 networks. They are used for the highest priority transmissions enabling stations with this type of information to access the radio link first. This value is established and computed in such a way that transmitting station will be able to switch back to receiving mode and be capable of decoding the incoming packets. Examples of information, which will be transmitted after the SIFS has expired, include the acknowledgement (ACK) and the Clear To Send (CTS) messages. The SIFS in IEEE 802.11 are defined to be the smallest of all interframe spaces (IFS). SIFS duration is a constant value and it depends on the amendments.

PCF Interframe Space (PIFS):

PCF Interframe Space (PIFS) is one of the interframe space used in IEEE 802.11 based WLANs. PCF enabled access point wait for PIFS duration rather than DIFS to occupy the wireless medium. PIFS duration is less than DIFS and greater than SIFS (DIFS > PIFS > SIFS). Hence AP always has more priority to access the medium. PIFS duration can be calculated as PIFS = SIFS + Slot time.

DCF, Distributed Coordination Function IFS (DIFS):

In the DCF protocol, a station has to sense the status of the wireless medium before transmitting. If the medium is continuously idle for DIFS duration then only it is supposed to transmit a frame. When the channel is sensed busy during the DIFS interval, the station must postpone its transmission. DIFS duration can be calculated as DIFS = SIFS + (2 * Slot time). If an AP finds that the medium is idle for a PIFS interval, it transmits a Beacon frame. A Beacon frame contains a CFP (Contention-Free Period) MaxDuration field. This value communicates the length of the CF period to all stations. Essentially, this value tells the user computers the maximum duration for which the AP will be controlling the medium. Computers receiving a Beacon frame update their NAV value with the CFPMaxDuration value. Consequently, user computers are prevented from taking control of the medium until the end of the CF period. This is because for a user computer to access the medium; first its NAV must reach 0. After transmitting a Beacon frame, the AP waits for at least one SIFS interval and next transmits one of the following frames:

- DATA frame
- CF Poll frame
- Data+CF Poll frame
- ACK frame
- CF End frame

DATA frame:

- This frame has user data from AP to a particular station.
- When the user receive the DATA frame, its sends back an ACK frame to the AP after an SIFS interval.
- If the AP does not receive an ACK, it can retransmit the frame after a PIFS interval.
- AP can also transmit broadcast and multicast DATA frames to all the users.
- Here we need to note the point that Broadcast and multicast frames are not ACK (acknowledged).

CF Poll frame:

- AP sends this frame to the user who agree to transmit a single DATA frame to any destination i.e. to the AP or another other user.
- Receiver of the above DATA frame sends back an ACK to the polled station.
- If the polled station has no DATA frame, it must send a null DATA frame.
- If a polled station does not receive an ACK, it cannot retransmit its data frame unless it is polled again.

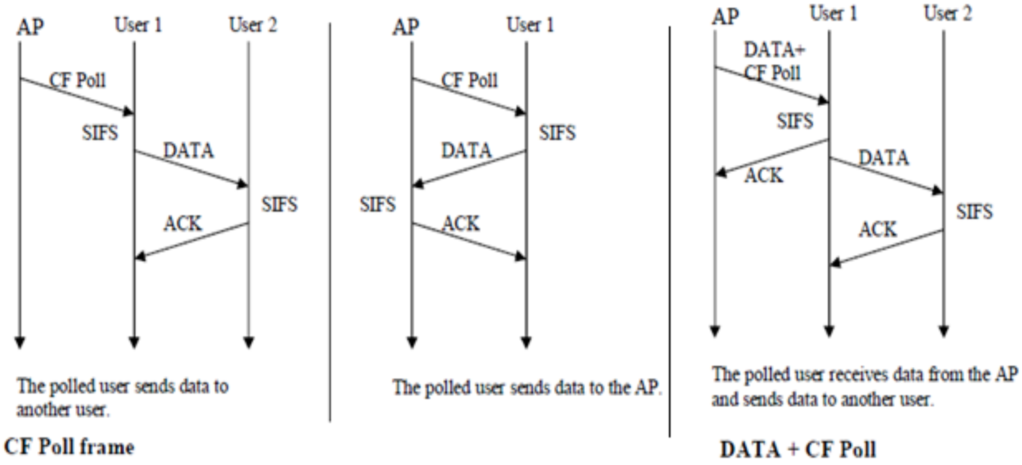


Fig 13: Data frames

CF End:

This frame identifies the end of the CF period. AP sends this when any one of the following happens:

- When AP has no data to transmit and no computer to poll. This can happen before the pre-announced CFPMaxDuration value expires. Thus AP can terminate its CF period before by transmitting a CF End frame. When the user receives this frame then it will reset their NAV as 0.
- When The CFPDurRemaining time expires. This variable is initialized with the value of CFPMaxDuration that was broadcast in a Beacon frame. As time passes, CFDurRemaining period is decremented and its value represents the remaining time for which the AP will be in control of the channel.

7.0.6 802.11 - CSMA/CA access method:

- It is ready to send starts sensing the medium, if the medium is free for the duration of an Inter-Frame Space (IFS), the station can start sending IFS depends on service type.
- If the medium is busy, the station has to wait for free IFS, and then the station must additionally wait a random back-off time.
- If another station in the medium during the back off its timer stops.

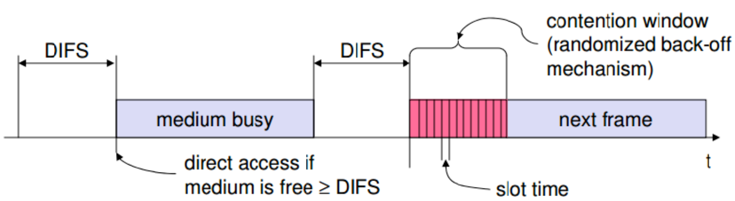


Fig 14: CSMA/CD Access method

7.0.7 QoS in DCF:

In DCF, only best effort service is provided. Time-bounded multimedia applications like voice over IP, video conferencing require certain bandwidth, delay, and jitter guarantees. The point is that with DCF, all the STAs compete for the channel with the same priority. There is no differentiation mechanism to provide better service for real-time multimedia traffic than for best effort traffic.

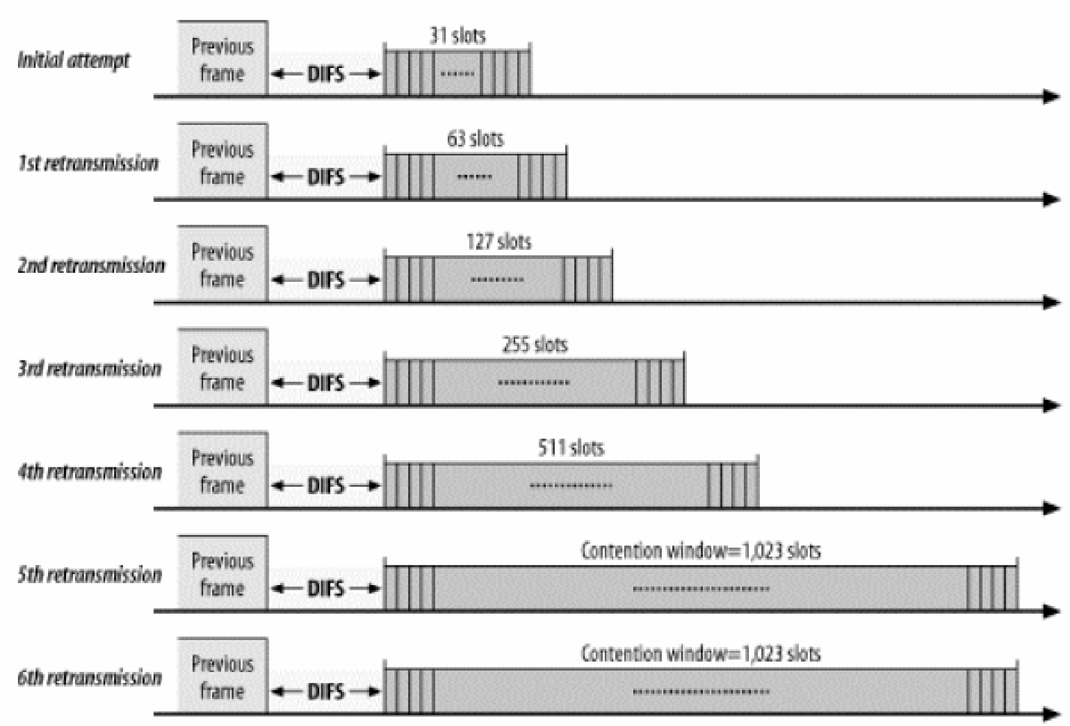


Figure 15: Different stages of retransmission

Backoff Time =Random () ×SlotTime

Random () = Pseudorandom integer drawn from a uniform distribution over the interval[0,CW]. It means when a station senses the medium to be idle again for a DIFS period, then it begins to wait another random times of the slottime. During the backoff time, if the medium is sensed to be idle for a whole slot, the generated random number is decremented with one, and if the medium is sensed to be busy, the backoff timer becomes suspended until the medium is sensed to be idle for the duration of DIFS and then the backoff procedure resumes. The station can start to transmit the pending frame if the backoff timer reaches zero. This procedure ensures that the station selecting the smallest backoff time using the random function will win the contention.

The value of CW range between CW_{min} and CW_{max}. It is possible that two stations which choose the same random number finish the backoff procedure and start to transmit simultaneously, which causes collision again.

To reduce the possibility of collision in this situation, each station maintains a CW window with different length. Initially CW is set to CW_{min} and its value doubles if a collision occurs until CW_{max} is reached. If the transmission is successful, the CW value reverts to CW_{min} before a new random backoff interval is chosen. Upon receiving a frame, the destination station waits for the duration of SIFS and responds with an ACK frame to notify the sender of a successful reception.

7.0.8 QoS in PCF:

PCF is designed in order to support time-bounded multimedia applications. It has three major problems that lead to poor QoS performance:

- PCF defines only a single-class round-robin scheduling algorithm, which cannot handle the various QoS requirements for different kinds of traffic.
- The AP schedules each beacon transmission at each TBTT, but the AP has to contend to access the medium. Depending on whether the wireless medium is idle or busy around the TBTT, the beacon frame may be delayed. With PCF, STAs are allowed to transmit even if the frame transmission cannot finish before the next TBTT. The duration of the beacon to be sent after the TBTT defers the transmission of data frames during the following CFP, which introduces delays to those data frames. In the worst cases like longest MSDU, Fragmentation, RTS/CTS, most robust modulation and coding scheme, the maximum delay of a beacon frame can be 4.9ms in WLANs and the average delay of a beacon frame might reach up to 250 s.
- Controlling the transmission time of a polled STA is kind off difficult job. A polled STA is allowed to send a frame of any length between 0 and 2304 bytes, which may introduce variable transmission time. Moreover the PHY data rate of a polled STA can change according to varying channel conditions. Thus, the AP is not able to predict transmission time. This prevents the AP from achieving guaranteed delay and jitter performance during the rest of the CFP interval.

Admission control mechanism was the major drawback in both DCF and PCF. When traffic load is very high, the performance of both functions can be degraded.

7.0.9 Limitations of IEEE 802.11 Legacy :

The two multiple access methods of DCF and PCF both have their limitations. DCF provides only best effort service and all stations contend for access to the medium with the same priority. Thus the DCF does not guarantee bandwidth, packet delay and jitter, and will have a throughput degradation in the heavy load environment. Although PCF allows for a better management of the QoS, the polling scheme in PCF is not efficient enough. So it has only been implemented in very few devices due to the lack of interoperability standard with other Wi-Fi devices.

8.0 IEEE 802.11e:

The IEEE 802.11e has been approved as a standard that defines a set of Quality of Service (QoS) mechanisms for WLANs. It differentiates traffic types and sources and is considered to be of critical importance for delay-sensitive and bandwidth-sensitive applications, such as streaming multimedia and wireless Voice over IP (VoIP). It gives solution for the QoS issues in the MAC sublayer.

IEEE 802.11e introduces two different medium access functions: a) centralized one and b) distributed one. In HCCA, the Access Point (AP) schedules transmissions through polling. Polling can be initiated by the AP at any time after a PIFS interval according to a vendor-dependent scheduling algorithm. EDCA employs four Access Categories (ACs) that are mapped into four separate queues. Frames are classified into these categories according to their IEEE 802.11D user priority. Each AC contends for the medium using the same rules but employs different channel access parameters. Using only these parameters, EDCA cannot guarantee any throughput or delay bounds, but only performance differentiation among the categories.

Additionally, IEEE 802.11e provides support for admission control. While the admission control algorithm is vendor-dependent but the signaling mechanisms used here are standardized. The QoS parameters used for characterizing a given traffic stream and deciding on its admission are referenced to as its traffic specification (TSPEC). Admission control is used for EDCA and HCCA. In the first case, the admitted traffic stream receives a portion of the channel resources in terms of admitted time, i.e., a maximum time interval within a one-second period in which the frames belonging to the stream can occupy the wireless medium. In the second case, since the AP coordinates channel access, an admitted flow receives the required transmission time if there are enough network resources. However, since the admission decisions are taken locally by each AP without any coordination mechanism with the neighbor cells, there is no guarantee that admitted flows will ultimately find a portion of idle channel equal to the admitted time.

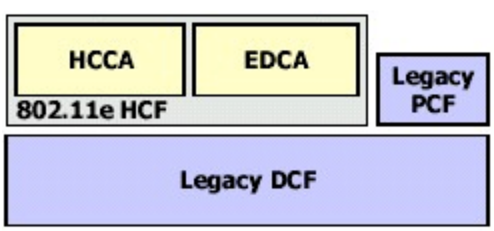


Figure 16 : IEEE 802.11e architecture

8.0.1 802.11e MAC protocol operation:

The 802.11e enhances the DCF and the PCF by introducing new coordination function called Hybrid Coordination Function (HCF). There are two methods of channel access used in HCF: one is a controlled channel access which is HCF Controlled Channel Access (HCCA) and other one is a contention-based channel access which is Enhanced Distributed Channel Access (EDCA). Generally emails can be assigned to a low priority class, and VOIP and Video streaming and conferencing can be assigned to a high priority class.

- EDCA is mechanism, which is used to prioritize the traffic streams.
- HCCA is used for parameterization of traffic streams.

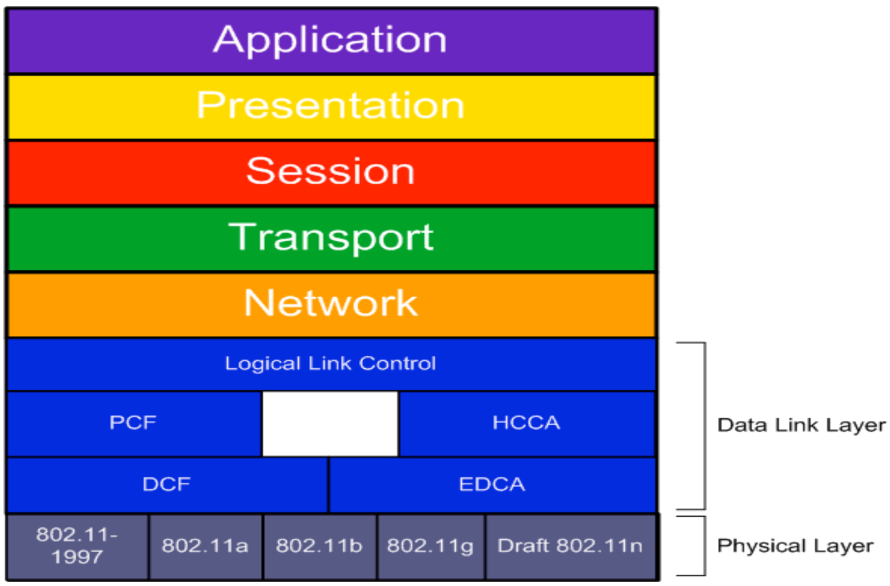


Fig 17: OSI layer representation after 802.11e amendment

8.0.2 HCF controlled channel access (HCCA):

HCCA is a mode of operation, which is based on controlled channel access mode. In both EDCA and HCCA, the transmission opportunity (TXOP) plays a vital role. The TXOP is an interval of time when a particular station has the right to initiate frame exchange sequences in the wireless medium. TXOP is determined by a starting time and a maximum duration. By successfully contending for the channel the TXOP is procured by the QSTA in EDCA, while in DCCA it's pre-assigned by the Hybrid Controller.

The HCF controlled channel access (HCCA) works mostly like PCF. However in contrast to PCF, the interval between two beacon frames is divided into two periods of CFP (Contention Free period) and CP (Contention period). It allows CFP being initiated at any time during a CP. This is known a Controlled Access Phase (CAP) in 802.11e. AP initiates a CAP 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 also CAP phase. During a CAP, the Hybrid Coordinator controls the access to the medium. All stations function in EDCA during Contention period. Here Traffic Class (TC) and Traffic Streams (TS) are defined. This shows that HC is not limited to per-station queuing but also it can provide per-session service. Also, the HC can coordinate these streams in any fashion it chooses. These stations give information about the queue length for each Traffic Class. The HC can use this info to give priority to one station over another and it adjust its scheduling mechanism.

HCCA is referred as the most advanced and complex coordination function. With HCCA, QoS can be configured with much accuracy. QoS-enabled stations have the privilege to request for certain transmission parameters like data rate, jitter etc. which makes applications like VoIP and video streaming to work more effectively on a Wi-Fi network. It maintains polled access to the wireless medium. Here QoS polling can take place during CP and scheduling of packets depends on the traffic requirements. When a station wants to join with a certain Basic Service Set, it mentions its requirements during Traffic specification (TSPEC) negotiation. The QoS stations send QoS reservation requests by using a special QoS management frame named Traffic Specification (TSPEC). It has the set of parameters that define the QoS characteristics of the certain traffic they are willing to transmit. An Admission Control Unit (ACU) in the QoS Access Point takes care of admitting or rejecting a new stream depends on the available resource and priorities.

The time period between two consecutive beacon frames is called a super-frame. It is classified as contention free period (CFP) and a contention period (CP). During CFP, Hybrid Coordinator controls the access to the channel by polling its associated stations through CF-Poll messages based on the QoS requirements.

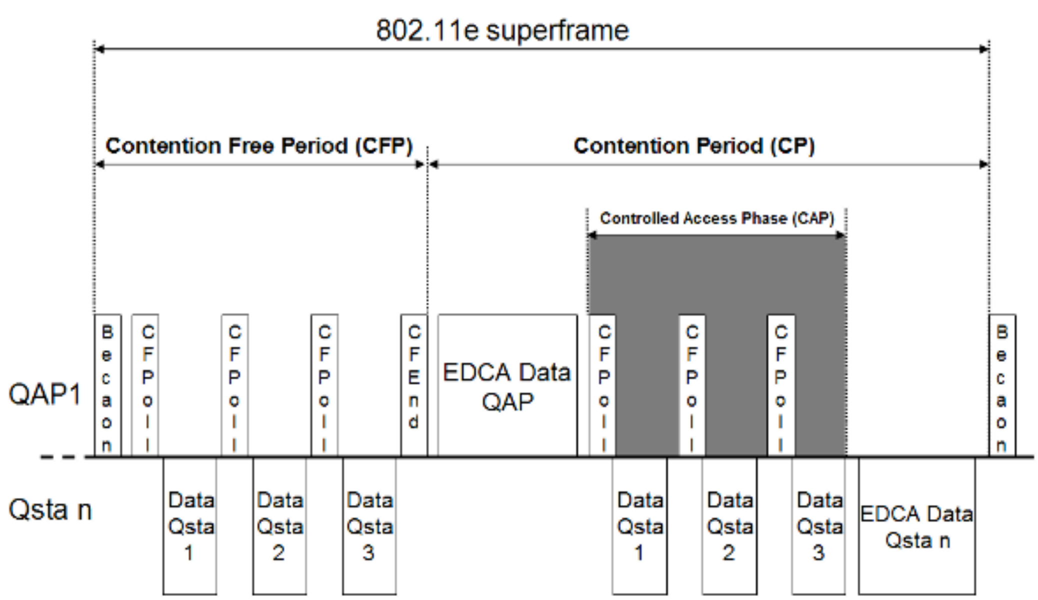


Fig18 : 802.11e Super-frame

HCCA is used in CPF and CP together with EDCA. The part of the CP accessed using polling is called Controlled Access Phase (CAP). Before accessing the channel, each station has to wait for an interframe space. As the interframe space of the HC is shorter than those of other stations, the HC has priority over any QoS Stations and it can allocate TXOP either to itself whenever it has a frame to send or to some other stations allowing them to deliver as many data frames as can be accommodated into the time allocated by the TXOP. As the HC allocates the TXOP through polling scheduler is needed to select the order in which stations has to be polled. The IEEE 802.11e standard does not impose a mandatory HCCA scheduling algorithm, but it offers a reference scheduler that respects a minimum set of performance requirements, on the basis of the mean data rate, nominal MAC Service Data Unit (MSDU) size and either maximum service interval or delay bound information provided by the TSPEC.

8.0.3 Enhanced Distributed Channel Access (EDCA):

EDCA is designed to provide prioritized QoS by enhancing the contention-based DCF. It provides differentiated, distributed access to the wireless medium for QoS stations by using 8 different user priorities. Before entering the MAC layer, each data packet received from the higher layer is assigned a specific user priority value. Tagging a priority value for each packet is an implementation issue. The EDCA mechanism defines four different first-in first-out (FIFO) queues, called access categories (AC) that provide support for the delivery of traffic with user priorities at the QoS stations. Each data packet from the higher layer along with a specific user priority value should be mapped into corresponding access categories.

Different kinds of applications like background traffic, best effort traffic, video traffic, and voice traffic can be directed into different access categories. In EDCA a new type of IFS is introduced, the arbitrary IFS (AIFS) in place of DIFS in DCF. Each AIFS is an IFS interval with arbitrary length as follows:
$AIFS[AC]=SIFS+AIFSN[AC]\times slottime$
where AIFSN[AC] is called the arbitration IFS number and determined by the AC and the physical settings, and the slottime is the duration of a time slot. The timing relationship of EDCA is shown in Figure. The AC with the smallest AIFS has the highest priority. The values of AIFS [AC], CW_{min} [AC], and CW_{max} [AC], which are referred to as the EDCA parameters, are announced by the AP via beacon frames. The purpose of using different contention parameters for different queues is to give low-priority rather than high-priority class, so the high-priority is likely to access the medium earlier than the low-priority.

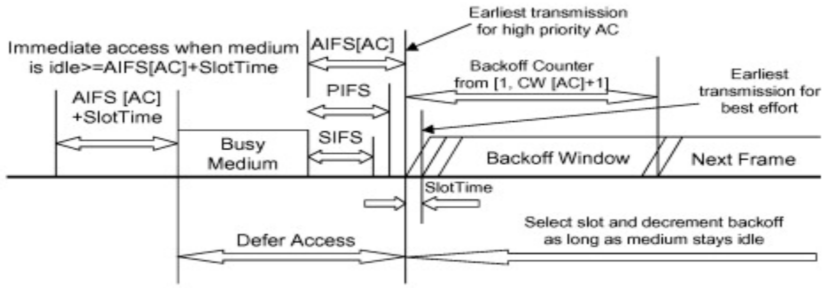


Fig 19 : EDCA

8.0.4 Timing relationship of EDCA

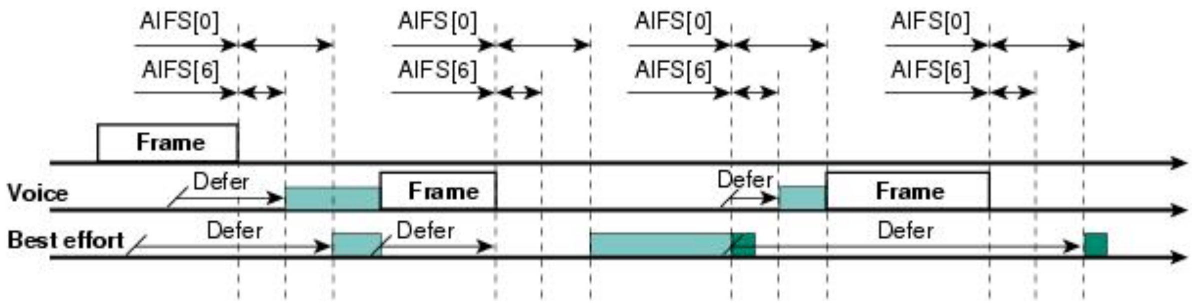


Fig 20 : Timing relationship of EDCA

8.0.5 Understanding EDCA:

EDCA contention access is similar to the legacy CSMA/CA DCF mechanism. But in EDCA we are including priorities. Here by adjusting the contention window and backoff times, we can change the probability of gaining medium access in order to favor higher priority classes. Here eight user priority levels are available. Each priority is mapped to access category, which in turn related to one of four transmit queues.

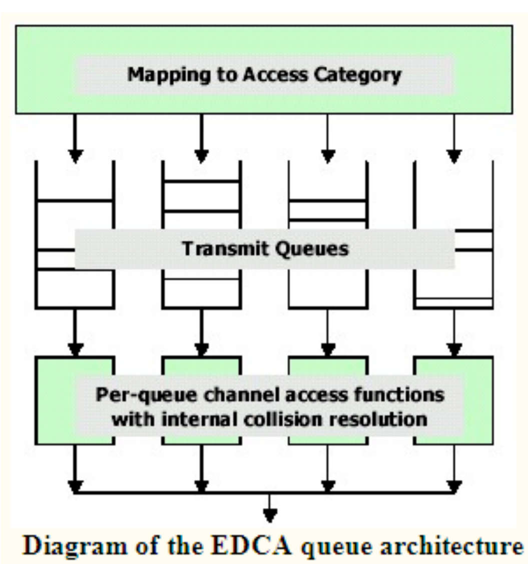


Fig 21: EDCA Architecture

Each queue provides frames to a independent channel access function, each of which implements the EDCA contention algorithm. When frames are in multiple transmit queue contention for the medium happens internally and externally depends on the same coordination function. Then only the internal scheduling resembles the external scheduling. Collisions, which happen during internal contention, will be resolved by allowing the frame with higher priority to transmit and the lower priority send from queue-specific backoffs if some collision has happened.

The EDCA mode classify the traffic into four Access Categories: AC_BK (background category), AC_BE (best-effort category), AC_VI (video category) and AC_VO (voice category). Here AC_VO has highest priority while AC_BK has the lowest. In order to manage the different ACs, EDCA implements in each node a dedicated transmit queue and an independent back-off entity for each AC. Each queue works as an independent DCF station and uses its own parameter set like the Arbitration Inter-Frame Space (AIFS), the minimum Contention Window size (CW_{min}), the maximum Contention Window size (CW_{max}) and the Transmission Opportunity limit (TXOPlimit). CW_{min} and CW_{max} determine the CW size. CW is set as CW_{min} at the very beginning. Failed transmissions will double CW until it equals CW_{max}. A successful one will reset CW to CW_{min}. TXOPlimit is the time duration a station may transmit after gaining access to the medium. Similarly to an 802.11 DCF node, each AC starts a back-off timer after sensing an idle channel for duration equal to an AIFS length. In DCF all nodes have the same probability to access the channel while in EDCA the AIFS depends on the AC. Its duration is shorter for the higher priority ACs so that it has a higher probability of accessing the channel than the lower ACs. Instead of DIFS, a station needs to defer for AIFS. It is obvious that smaller CW_{min}, CW_{max}, and AIFS will lead to better chance of gaining the medium. Fig.22 illustrates the EDCA operation.

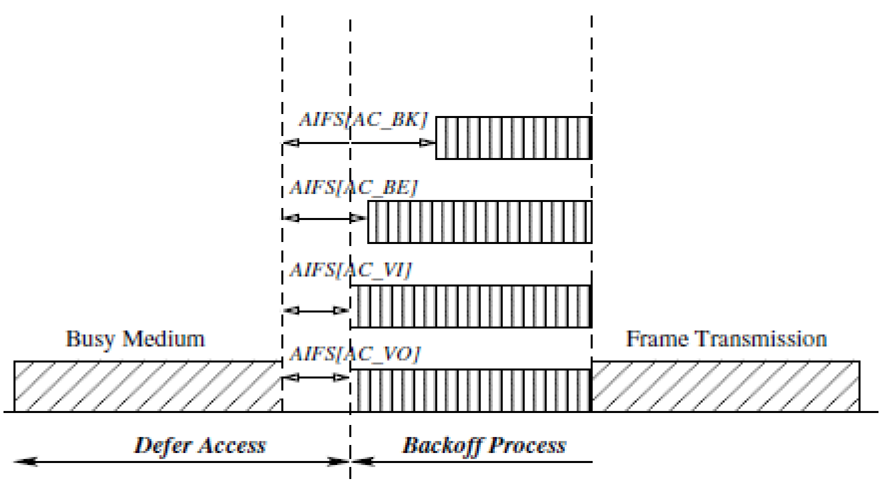


Fig 22 : EDCA operation modes

The EDCA implementation model is shown in figure 23. Once the data arrives at the MAC sub-layer, it is grouped according to appropriate AC, and kept AC transmission queue for transmission. In the queue there will be other frames too which will also ready for transmission and compete for channel access internally within the station. The internal contention algorithm calculates the backoff, independently for each AC, based on AIFSN, contention window, and a random number. The backoff procedure is similar to the principle used in DCF and AC with the smallest backoff gets priority in the internal contention. If the backoff time of more than one AC counts down to zero at the same time then internal collision occurs within a station. These collisions are resolved such that the frames in the high-priority AC receive the TXOP whereas the frames in the low-priority AC act as if there was an external collision on the wireless medium.

AC, which gets priority in internal contention, would then contend externally for the wireless medium. The external contention algorithm has not changed much compared to DCF except that in DCF the backoff and deferral are constant for a particular PH. But in 802.11e the backoff and deferral are considered as variable, and the values are determined according to the appropriate AC.

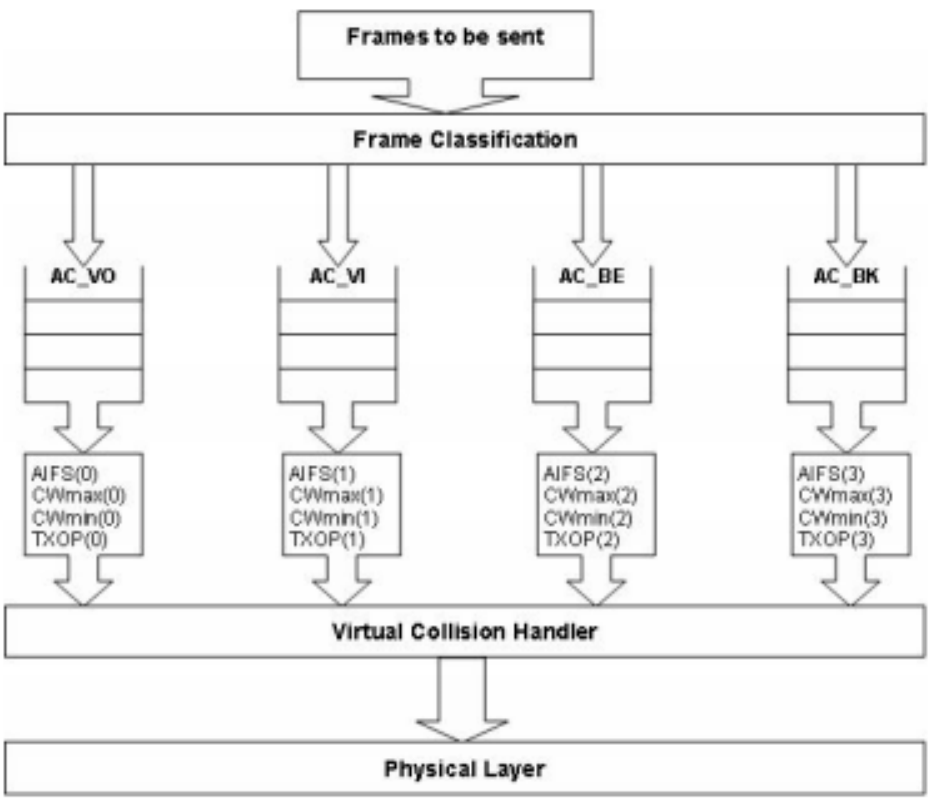


Fig: 23 EDCA implementation model

8.0.6 QoS limitations on EDCA:

The packet classification per AC in EDCA is only for the internal traffic flows, so EDCA sort of mechanisms to manage priorities among transmissions from different stations in the coverage area of the network. This limitation may lead to the following problems:

- Parallel access per AC: This situation occurs when other stations in the WLAN simultaneously transmit packets in the same AC. This might lead to large contention delays, which will affect performance improvement achieved by EDCA.
- Static assignment of AIFS: When the access ratings for high priority traffic are inactive, the low priority traffic classes are forced to wait long AIFS periods before the backoff process restarts the count to zero. Because of that aggregated throughput may be affected.
- Intra-AC differentiation: EDCA does not provide any mechanism to monitor the state of the rest of the stations in the network from each station. When multiple stations with the same priority choose the same backoff values, it will increase the amount of collisions in the network.

8.0.7 QoS limitations Enhancement on EDCA:

To enhance the QoS limitations, we proposed mechanism to minimize the high collision rates of EDCA during periods of heavy traffic. Its algorithm is based on a random selection of CW and AlFS. Our prime goal is to prevent the different entities in an AC should not choose the same set of values during the backoff process. This new access mechanism is compatible with the original IEEE 802.11e EDCA scheme. Here TXOP is obtained according to an inter-station priority scheme based on the amount of local traffic. This clears the fact that the transmission of packets is based not only on the AC priority but also on the effective channel capacity. Now we proposed hybrid mechanism ACI-EDCA that combines the above-mentioned mechanism. In the mean time the performance of the network is better optimized.

9.0 ACI-EDCA Mechanism:

ACI-EDCA is a scheme implemented for EDCA based on the activity going in each stations in the network and on packet loss rate. It applies a adaptive scheme on AIFS and the backoff interval based on the individual perception of each station from state of the transmission medium, the competing conditions in the WLAN and the effective throughput. The main objective of this mechanism is to establish a relationship between the MAC algorithms based on priorities inherited from EDCA and the information obtained in real time by each of the sessions of the stations. There is no adjustment mechanism that assigns the parameters establishing the priorities of traffic categories, as EDCA is a distributed scheme. This mechanism is used for the traffic of different categories as well as for the relative priority of traffic flows over other flows in the same category. This mechanism is also called as priority inter-station scheme and inter-AC differentiation.

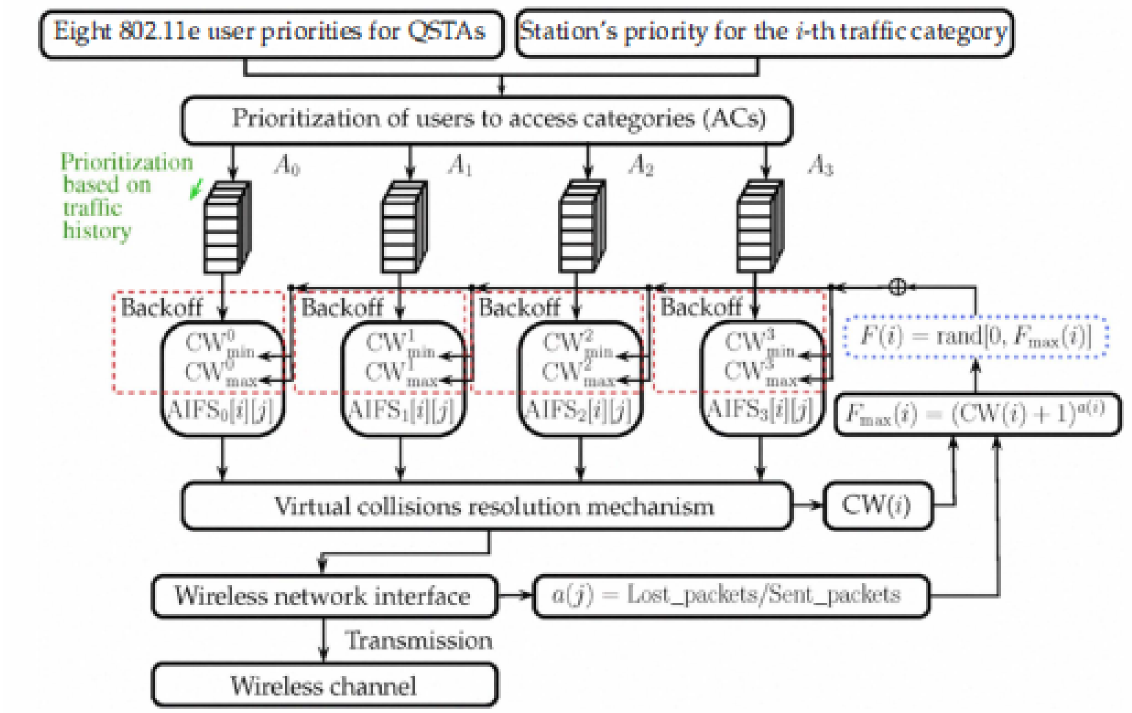


Fig: 24 Active Classifying Inter-Station Scheme for EDCA

This mechanism shows a significant change in the performance of the original IEEE 802.11e EDCA algorithm. We can witness performance improvement by measuring the wireless medium parameters like delay, jitter, throughput, and the amount of collisions occurred during transmissions. However the assumptions made During the implementation a non-adaptive scheme, some assumptions made which is actually prone to advancement on the contention window during the backoff period or AIFS period. Either case both parameters are underestimated and as a result the algorithms proposed are insignificant which results in decreasing the synchronism between traffic categories of low priority and the randomness of the AIFS value.

The obtained result is combination of both adaptive and complimentary techniques. The complimentary technique might reduce the ability of self-managing the traffic flows in each stations. It is based on the state of the transmission medium and the competing conditions per AC. This proposal reduces the packet losses in the transmission medium and the competing conditions in the WLAN are improved.

The collision rate is adapted and the loss rate in our ACI-EDCA algorithm is obtained as follows:

$$a(i)_{avg} = (1-\alpha)a(i) + \alpha a(i-1)_{avg}$$

Where i refers to the i-th measurement period and a is absorption factor in [0, ..., 1]. Algorithm I shows how the contention window is updated in ACI-EDCA. The shown in Algorithm 2 the adaptive scheme for updating the AIFS value on our ACI-EDCA mechanism. Here we have make note the point that the amount of new mobile categories to establish the activity of a given station depends only of the value of max_traffic_priority. The new mobile category provides additional differentiation among active transmission requests in the same AC.

9.0.1 Algorithm 1 - Dynamic method to update CW values based on RAMPS :

Input = Lost packets L (i), Sent Packet S(i)

Output = Total backoff time(T)

if (first station transmission in AC) then

$\alpha_{AC}(i) = 0;$

$\alpha_{AC}(i)_{avg} = 0;$

else

$\alpha_{AC}(i) = (L(i-1)-L(i))/(S(i-1)-S(i));$

$\alpha_{AC}(i)_{avg} = (1-\alpha).\ \alpha_{AC}(i) + \alpha.\alpha_{AC}(i-1)_{avg};$

endif

$F_{max}(i) = [CW(i)+1]^{\alpha_{AC}(i)avg}$

$F(i) = rand(0,F_{max}(i));$

$T = rand(1,CW(i)+1)+F(i);$

Return T

9.0.1.a Explanation of algorithm :

BackOff time in general is a random number between 1 and contentionwindow+1. If the Station is not in AC, the backoff time will be more. The value is again a random number which depends on the ratio of average delay ($\alpha_{AC}(i)_{avg}$) . $\alpha_{AC}(i)_{avg}$ is the average of all α_{AC} where α_{AC} is the ratio of packet loss. $\alpha_{AC}(i)$ is mean the packet loss of that particular station.

The actual formula which we could use for the above explanation given below

αAC(i)avg = (1-α). αAC(i) + α. αAC(i-1)avg

Where $\alpha_{AC}(i)$= value of α_{AC} at an instant i = Ratio of packets lost during that time to the packets sent during that time = L(i-1)-L(i)/S(i-1)-S(i) which is always less than Zero.

and $\alpha_{AC}(i)_{avg =}$ value of α_{AC} average at an instant i. Here We are not calculating an exact mathematical average , We are calculating average based on a typical value of the system.

The current average is calculated from parts of old average, and the remaining parts from the new average How many parts of old average and new αAC is defined by αAC . Lets say you have an average of 10 , which is average of some random 5 numbers, and a 6th number comes in, lets say its 8, so average changes, Mathematically, you would do is (10*5+8)/6 = 9.67. Here, we ignore that the average is made up from 5 previous numbers, Lets say we just have a average, and a new number comes in, here we take previous Average=10 , New number =8 .We need another value α, Lets say α=0.5, so 1-α is also 0.5.Which means we give equal importance to old average and the new current delay. It will be 10*0.5+8*0.5 = 9 , But in most cases, the previous average is given more importance, as its calculated over a period of time and presumed to be stable, So lets consider α to be 0.75, so 1-α will be 0.25. This means is we give 3/4th importance to old average and 1/4th to the current value. So 10*0.75 + 8*0.25 = 9.5 , So here we can see the difference, α always ranges between 0 to 1, it is generally fixed for your system or algorithm. Now, we know about αACavg. Let compute the random number which depends on αACavg , we can name that random number as F(i) or F ,

We use the formula, $F(i) = rand(0,F_{max}(i))$.

Where $F_{max}(i) = [CW(i)+1]^{\alpha_{AC}{}^{(i)avg}}$

This value, F(i) would always be 0 if station is in AC(Assumption according to this algorithm: rand(0,1)=0). αAC(i)avg is always less than 1, so F(i) will always be more than 1 if station is not in AC. ..We add this random number to 'rand(1,CW(i)+1)' which resulting in a total backoff time as T = rand(1,CW(i)+1)+F(i);

9.0.2 Algorithm 2 - Dynamic method to update AIFS values :

```
  Input: Transmission request in wireless terminal n for ACi.
  Output: mobile category j update
     if(aifs_plus_j==0) then
aifs_plus_j = AIFS_up_AC – (1x10-6) – AIF_static/max_traffic_priority;
endif
     if (  (packet_count_ACO || packet_count_AC1) == max_traffic_priority) then
         (packet_count_AC0 || packet_count_AC1) = 0;
     else
        if AIFS <AIFS_up_AC  then
            AIFS = AIFS + aifs_plus_j;
endif
endif
  if ((packet_count_AC2 || packet_count_AC3)== max_traffic_priority) then
    (packet_count_AC2  || packet_count_AC3) = 0;
  else
     if  (AIFS >AIFS_down_AC) then
          AIFS = AIFS – aifs_plus_j;
endif
endif
```

10.0 Simulation Scenario:

This section describes the different traffic sources in our scenario:

Fig: 25 Simulation scenario

Video Source: A video traffic source by an ON/OFF process with the following relationship:

$$\lambda_{on/}\ \lambda_{off} \approx [0.399,0.547]$$

Once set the parameter of the exponential distribution for the ON or the OFF period, the set of values for the other period is bounded. For simplicity, fix the traffic load to 0.5 and determine the parameter of the exponential distribution of the ON period based on theH.264/MPEG-4 AV C standard for video compression.

• **VolP Traffic**: Voice traffic is characterized by a Poisson source and take the parameters of the G.729standard with a bit rate of 8 kbps and average bandwidth of 11.2 kbps per VoIP call.

• **Best-effort Traffic**: Inject into the network best-effort traffic as CBR traffic of 1 Mbps.

• **Background Traffic**: This traffic is injected as a Poisson source of 400 kbps. For this simulation we consider the simulation parameters in Table 1. Each station is in a range of 25 meters of the coverage range of an access point. In order to introduce variability in the network topology, vary the amount of active stations in the WLAN up to 30 stations. The simulation starts with 5 active stations, every 1000 seconds we add 5 stations to the basic service set (BSS) served by the access point (AP).

	Voice	Video	Best-effort	Background
Model	Poisson	IPP	CBR	Poisson
Transport protocol	UDP	UDP	TCP	UDP
AC	VO	VI	BE	BG
CW_{min}	7	15	15	31
CW_{max}	15	31	1023	1023
AIFS	30 μs	50 μs	70 μs	150 μs
Packet size	250	510	250	250
Sending rate	11.2 kbps	1512 kbps	1024 kbps	400 kbps

Table I - SIMULATION PARAMETERS

When the amount of served stations reaches 30 and after 1000seconds, the WLAN returns to the minimum amount of 5 active stations and the simulation cycle is restarted. When a station at the beginning of a simulation, it will try to establish two bidirectional VolP calls, it will start a video-streaming session and it will establish bi-directional background and best-effort flows. Each of the traffic sources starts its transmission in a random fashion and independently from the rest of the traffic sources. The MAC and physical layer parameters considered in simulations are shown below.

Parameter	Value
SIFS	10 μs
PIFS	30 μs
DIFS	50 μs
Slot time	20 μs
Data rate	11 Mbps
Minimum rate	1 Mbps

Table II - SIMULATION PARAMETERS FOR PHY AND MAC

10.1 Simulation Results :

10.1.1 Simulation Design for collision packets:

Coding : aci_col.docx

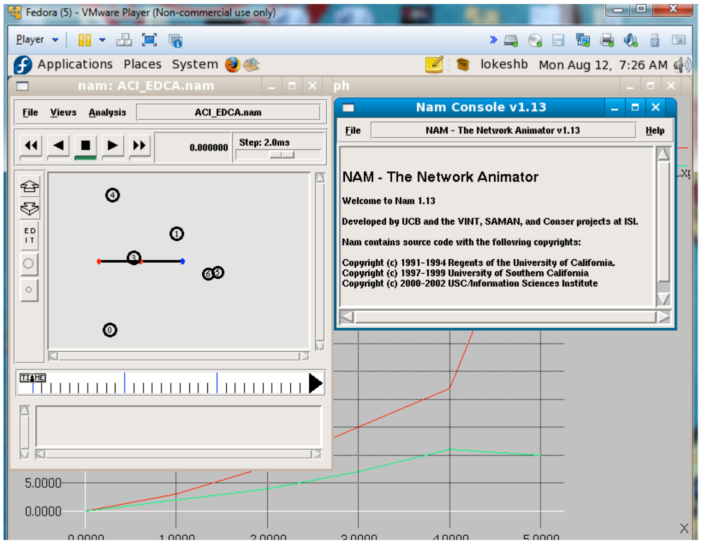


Fig 26 : NAM design for collision packets

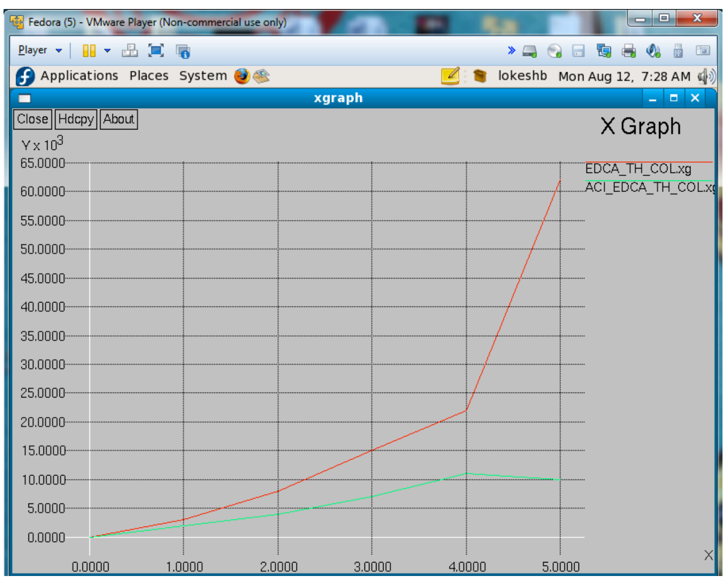


Fig 27 : Graphical output for Collision packets
(X-Axis = Wireless stations in WLAN,
Y-Axis = Packets)

Figure.27 shows the performance comparison on collisions for EDCA and ACI-EDCA. This clearly shows that the proposed method able to increase the throughput in the network since the number of packet retransmissions is reduced considerably when compared to EDCA.

10.1.2 Simulation Design for Average BK traffic throughput in WLAN:

Coding : ACI_BK.docx

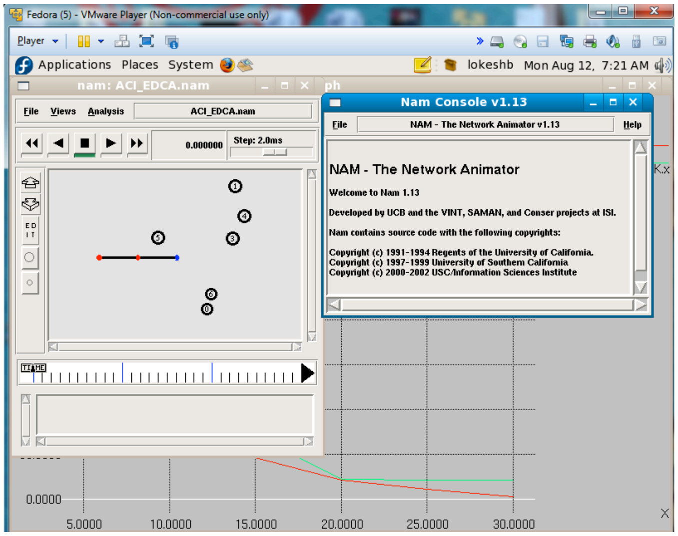


Fig 28 : NAM design for average BK traffic throughput

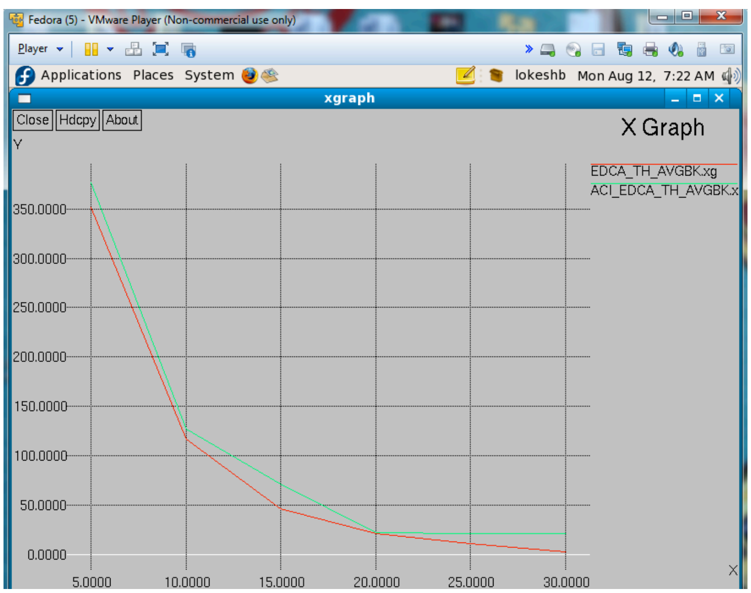


Fig 29: Graphical output for average BK traffic throughput
(X-Axis = Wireless stations in WLAN,
Y-Axis = Throughput x10^3 kb/s)

Figure 29, shows the performance comparison on throughput with reference to number of wireless station in the WLAN for EDCA and ACI-EDCA. This clearly shows that the proposed method able to increase the throughput in the network since the number of wireless stations is increased.

10.1.3 Simulation Design for Average BE traffic throughput in WLAN:

Coding : ACI_BE.docx

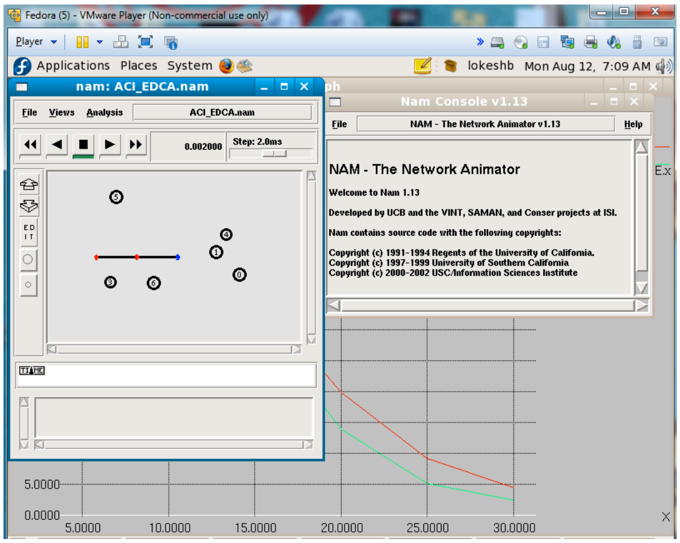


Fig 30 : NAM design for average BE traffic throughput

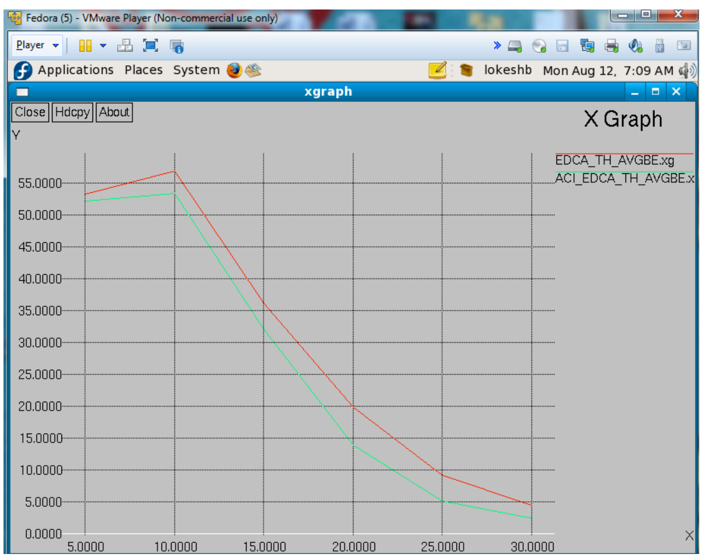


Fig 31 : Graphical output for average BE traffic throughput
(X-Axis = Wireless stations in WLAN,
Y-Axis = Throughput x10^3 kb/s)

Figure 31,shows the performance comparison on throughput with reference to number of wireless station in the WLAN for EDCA and ACI-EDCA. This clearly shows that the proposed method able to decrease the throughput in the network since the number of wireless stations is increased due to the algorithm is more restrictive and as the result the throughput decreases.

10.1.4 Simulation Design for Voice traffic in WLAN:

Coding :

ACI_voice.docx

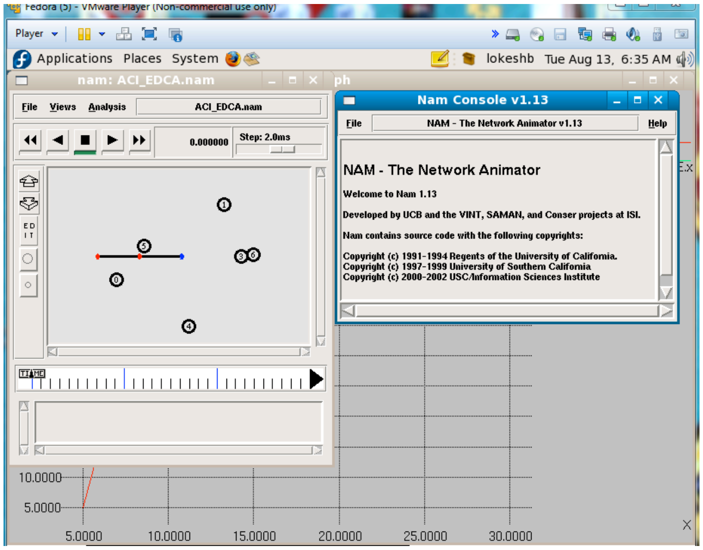


Fig 32 : NAM design for Voice traffic throughput

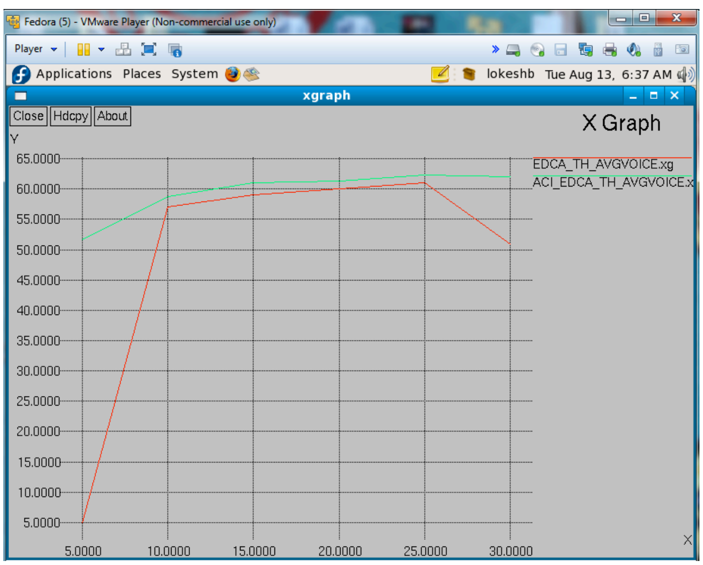


Fig 33 : Graphical output for Voice traffic throughput
(X-Axis = Wireless stations in WLAN,
Y-Axis = Throughput x10^3 kb/s)

Figure 33, shows the performance comparison on throughput with reference to number of wireless station in the WLAN for EDCA and ACI-EDCA. This clearly shows that the proposed method able to increase the throughput in the network since the number of wireless stations is increases.

10.1.5 Simulation Design for Video traffic in WLAN:

Coding : ACI_video.docx

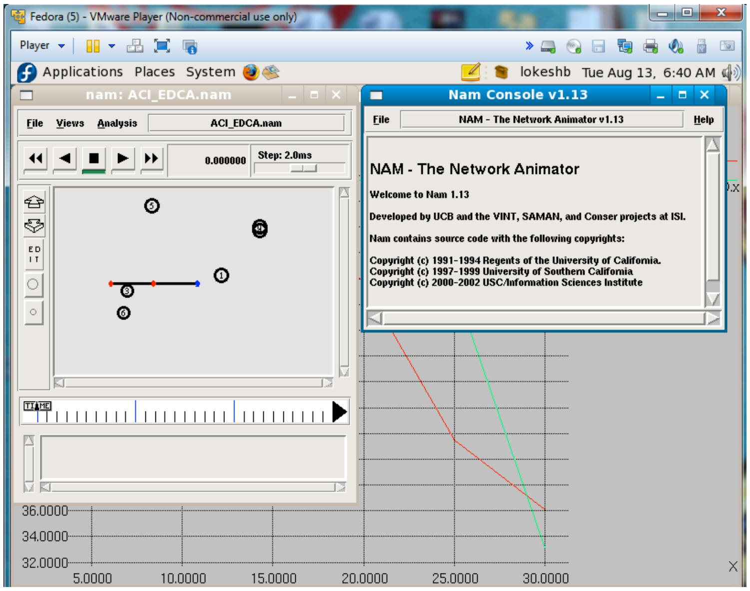


Fig 34 : NAM design for Video traffic throughput

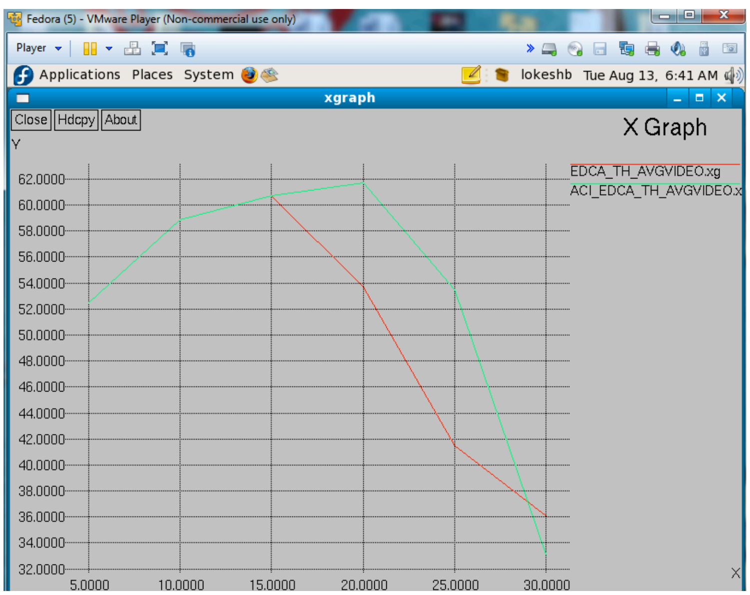


Fig 35 : Graphical output for Video traffic throughput
(X-Axis = Wireless stations in WLAN,
Y-Axis = Throughput x10^3 kb/s)

Figure x shows the performance comparison on throughput with reference to number of wireless station in the WLAN for EDCA and ACI-EDCA. This clearly shows that the proposed method able to increase the throughput in the network since the number of wireless stations is increased.

11.0 CONCLUSION:

The proposed in this work is a hybrid EDCA algorithm to provide QoS in IEEE 802.l1e WLANs. The proposed ACI-EDCA algorithm provides inter-AC differentiation while adapting the transmission rate per AC depending on the medium conditions. ACI-EDCA estimates the channel capacity to provide differentiated services of traffic with different QoS requirements. This algorithm is a two-phase algorithm based on the loss rate per station and the activity per class of traffic. One of the most important results obtained is that our ACI-EDCA algorithm out performs previously proposed algorithms in the collision rate. This allowed increasing the throughput per AC allowing to obtain better results in QoS for multimedia traffic. So, ACI-EDCA exhibits a better differentiation per AC.

In Mint 702 course (Data communication protocol), I learnt about IEEE 802.11 standard, which is standard approved for WLANS by IEEE. IEEE 802.11 is a standard, which has multi-vendor interoperability and lower prices over the air-interface exactly the same as Ethernet 802.3 standard, which does it through Ethernet cable. The main features I learnt about this standard is that its robust architecture because of its acknowledgement, RTS/CTS and fragmentation. It allows multiple channel roaming and consumes less power compared to other standards. Here automatic rate selection drops to 1Mbps which makes the connection stays for longer time. But still MAC layer strategy and physical variability with transmission medium causes limitations in bandwidth, packet loss, waiting time and mobility. Implementing TCP over IEEE 802.11 standard reduced due to low reliability, mobility and very long Round trip times. This causes issues with Quality of service with WLANs. With IEEE 802.11 standard, Multimedia traffic over WLAN has restricted bandwidth and delay-sensitive. So I understood from the studies through the further papers and articles that IEEE 802.11 MAC mechanism is not provided with quality of service (QoS) and quality packet delivery of multimedia over the conventional 802.11 WLAN is challenging task.

So I came to know by further studies that the IEEE 802.11e standard was schemed to provide multimedia service differentiation. It provides service differentiation in the MAC layer by a special congestion control/avoidance mechanism based on the concept of access category queues within a mobile station. The conventional DCF function of 802.11 MAC has only a single first-in-first-out (FIFO) queue so that collisions occur among the wireless stations when they try to access the wireless channel simultaneously, whereas the enhanced distributed channel access (EDCA) of 802.11e MAC offers multiple prioritized AC queues. Like that MAC layer also provides differential support to the packets depends on the different QoS requirements while transmitting to upper layers. In original standard Point Coordination function (PCF) and Distributed Coordination function (DCF) is replaced by two hybrid Coordination functions HCF controlled channel access (HCCA) and Enhanced Distributed Channel Access (EDCA). Every station has four independent EDCAF(Enhanced Distributed Channel Access Function). AC's classified as best effort (AC_3), background (AC_2), video (AC_1) and voice (AC_0). I clearly understood that AC with highest priority has the shorter CW so that the highest priority traffic can be transmitted prior than others and given priority. The CW is determined from the range of CWmin [AC] and CWmax [AC] which is calculated for different values of ACs. Different Interframe spaces (IFS) are used according to different ACs. Transmission begins if the channel is sensed idle, otherwise the stations executes a back-off procedure after waiting a period of AIFS[AC]. The back-off time is drawn from the interval [1, CW [AC] +1]. Each AC within a single station behaves like a virtual station that can independently start transmission if the channel is idle.

In IEEE 802.11e standard a new feature named as transmission opportunity (TXOP) is introduced. It is defined by a start time and duration. In this time period a station can deliver multiple MPDUs consecutively without contention with other stations. This mechanism called as Contention-Free Bursting (CFB), which gives better throughput. The frame exchange mechanism of IEEE 802.11e is quite similar to that of IEEE 802.11 but here additional feature has been incorporated. Here by attaching ACK or a poll for certain QoS Station to a previously received frame so that the number of frames to be transmitted is reduced and we can reduce the overhead.

In this study, I used NS2 simulator in order to simulate the scenario mentioned. It is open source discrete even simulator used for networking research, which simulate wired and wireless networks and support many protocols. I learnt how to install the setup in Linux environment by using online tutorials after two or three failure attempts. When I started to install NS2 in my Linux platform I received errors like autoconf and makefile not found. Then I found the way to install those files through online forums and make my simulator working in my Linux platform before starting the module. Then I used online tutorial and basic book about NS2 in order to learn about how to use the simulator. After studying the basic concepts and simpler programs started to develop the code for the study I took in this report.

From the simulation I have done to compare the performance on throughput for the four categories of traffic. For background traffic, it is evident that our proposal provides a clear increase in throughput for background traffic. For best-effort traffic the proposed algorithm is more restrictive so that the throughput decreases. Finally the most significant step in the proposal i.e. enhancing multimedia traffic for video and voice traffic we can infer from our graphs that our ACI-EDCA algorithm outperforms the previously proposed mechanism for the transmission of multimedia traffic. This is a significant result of this study since we are concerning to provide a better QoS for multimedia traffic in IEEE 802.11e WLANs.

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