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## **MASTER MEMORY**

SPECIALITY : COMPUTER SYSTEM AND NETWORKS

### **IEEE 802.11.e PROTOCOL PERFORMACE ASSESSMENT**

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# Thanks

First of all, we would first like to thank Almighty God for giving us the strength, the health and the will to carry out this work.

At the end of this job, I would like to express a sincere thanks to all the people who have contributed directly or indirectly to its realization .

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I am thankful as a worker in this paper. My deceased father ALLAH god almighty gave him heaven. How woos my first and best teacher in my life .

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Tanks all

# Dedication

I dedicate this humble work:

to our parents, for their sacrifices , there tenderness and there prayers throw  
out our studies

to my father how say to me i will give you and pay for you what you need you  
just keep studies and keep going in to the top ,to all our family to all my friend, to  
anyone who believed in us and helps us throw this time

Abdelmoumen & kamale

# Abstract

The IEEE 802.11 wireless local area networks (WLAN) are widely deployed and popular WLAN technologies worldwide. As the demand for multimedia applications like VoIP and video streaming grows, there is a need to provide Quality of Service (QoS) in 802.11 WLANs. To address this, the IEEE 802.11e standard introduced an enhancement called Enhanced Distributed Channel Access (EDCA) using a contention window.

This thesis comprises three parts. Firstly, an overview of the IEEE 802.11 standard and its DCF mechanism is provided, highlighting the limitations. Then, a detailed study is conducted on the mechanisms used to support QoS in the IEEE 802.11e standard and its improved variants.

The second part focuses on analyzing the differentiation capabilities of important EDCA QoS parameters in ad hoc WLANs, specifically using throughput analysis. This analysis aims to provide insights on how to effectively apply QoS settings to meet the QoS requirements.

In the final part of the research, a comparison is made between the proposals of the IEEE 802.11e standard and the baseline IEEE 802.11 standard. Simulations using the NS3 simulator are performed to evaluate these standards, and a comprehensive discussion is presented based on the simulation results. The research confirms the enhanced QoS capabilities of IEEE 802.11e compared to IEEE 802.11

**Keywords:** Wireless Local Area Network (WLAN), IEEE 802.11, IEEE 802.11e, DCF, EDCA, Quality of Service (QoS), WLAN, mac.

## خلاصة الموضوع

تم نشر شبكات IEEE 802.11 المحلية اللاسلكية (WLAN) على نطاق واسع وتقنيات WLAN الشعبية في جميع أنحاء العالم. مع تزايد الطلب على تطبيقات الوسائط المتعددة مثل VoIP وتدفق الفيديو، هناك حاجة إلى توفير جودة الخدمة (QoS) في IEEE 802.11 شبكة WLAN. لمعالجة هذا، أدخلت معيار IEEE 802.11e تحسينات تسمى الوصول المحسن للقنوات الموزعة (EDCA) باستخدام نافذة خلاف. تتألف هذه الأطروحة من ثلاثة أجزاء. أولاً، يتم تقديم نظرة عامة على معيار IEEE 802.11 وأليته DCF، مما يسلط الضوء على القيود. وبعد ذلك، يتم إجراء دراسة مفصلة حول الآليات المستخدمة لدعم جودة الخدمة في معيار IEEE 802.11e ومتغيراته المحسنة. ويركز الجزء الثاني على تحليل قدرات التمايز لبارامترات جودة EDCA المهمة في الشبكات المحلية اللاسلكية المخصصة، وتحديدًا باستخدام تحليل الإنتاجية. يهدف هذا التحليل إلى توفير رؤى حول كيفية تطبيق إعدادات جودة الخدمة بشكل فعال لتلبية متطلبات جودة الخدمة. وفي الجزء الأخير من البحث، أجريت مقارنة بين المقترحات الواردة في معيار IEEE 802.11e ومعيار IEEE 802.11 الأساسي. يتم إجراء عمليات محاكاة باستخدام جهاز محاكاة NS3 لتقييم هذه المعايير، ويتم تقديم مناقشة شاملة استنادًا إلى نتائج المحاكاة. يؤكد البحث قدرات QoS المحسنة لمعيار IEEE 802.11e مقارنة بمعيار IEEE 802.11

الكلمات الدالة: الشبكات المحلية اللاسلكية ، IEEE 802.11 ، IEEE 802.11e ، DCF ، EDCA ، QoS ، WLAN ، mac.

# Résumé

Les réseaux locaux sans fil (WLAN) IEEE 802.11 sont des technologies WLAN largement déployées et populaires dans le monde entier. Alors que la demande d'applications multimédias telles que la VoIP et le streaming vidéo augmente, il est nécessaire de fournir une qualité de service (QoS) dans les WLAN 802.11. Pour résoudre ce problème, la norme IEEE 802.11e a introduit une amélioration appelée Enhanced Distributed Channel Access (EDCA) utilisant une fenêtre de contention.

Cette thèse comprend trois parties. Tout d'abord, un aperçu de la norme IEEE 802.11 et de son mécanisme DCF est fourni, en soulignant les limites. Ensuite, une étude détaillée est menée sur les mécanismes utilisés pour supporter la QoS dans la norme IEEE 802.11e et ses variantes améliorées.

La deuxième partie se concentre sur l'analyse des capacités de différenciation des paramètres QoS EDCA importants dans les WLAN ad hoc, en utilisant spécifiquement l'analyse du débit. Cette analyse vise à fournir des informations sur la manière d'appliquer efficacement les paramètres QoS pour répondre aux exigences QoS.

Dans la dernière partie de la recherche, une comparaison est faite entre les propositions de la norme IEEE 802.11e et la norme de base IEEE 802.11. Des simulations à l'aide du simulateur NS3 sont effectuées pour évaluer ces normes, et une discussion complète est présentée sur la base des résultats de simulation. La recherche confirme les capacités QoS améliorées de l'IEEE 802.11e par rapport à l'IEEE 802.11

**Mots clés** : Réseaux locaux sans-fil, IEEE 802.11, IEEE 802.11e, DCF, EDCA, QoS, WLAN, mac.

## Abbreviations

AC	Access Category
AP	Access Point
AIFS	Arbitrary Inter-frame Spacing
BSS	Basic Service Set
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CSMA/CD	Carrier Sense Multiple Access with Collision Detection
CW	Contention Window
CR-EDCF	Collision Rate-based Adaptive EDCF
DCF	Distributed Coordination Function
DSSS	Direct Sequence Spread Spectrum
DIFS	DCF Interframe Space
EDCA	Enhanced Distributed Channel Access
EDCAF	Enhanced Distributed Channel Access Function
FHSS	Frequency Hopping Spread Spectrum
HCF	Hybrid Coordination Function
IP	Internet Protocol
IR	Infrared
ISM	Industrial, Scientific and Medical
IBSS	Independent Basic Service Set
MAC	Media Access Control
NS3	Network Simulator3
OFDM	Orthogonal Frequency Division Multiplexing
PCF	Point Coordinator Function
PC	Point Coordinator
PIFS	PCF Inter-Frame Space
PHY	Physical
QoS	Quality-of-Service
QSTA	Quality of Service Station
SIFS	Short Inter-Frame Space

TXOP	Transmission Opportunity
VoIP	Voice over IP
WLANs	Wireless Local Area Networks
VI	Video
BK	background
VO	Voice



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# GENERAL INTRODACTION

## 1 Introduction :

The rapid development of information technologies in our unprecedented world has led to the information revolution, enabling the processing, storage, and transmission of vast amounts of data in real-time. Wireless network technology, such as IEEE 802.11, has played a significant role in this revolution due to its cost-effectiveness, speed, and easy installation.

With the increasing demand for quality of service (QoS) in multimedia applications, research has focused on guaranteeing QoS in networks. The IEEE 802.11 standard, which describes the physical layer (PHY) and MAC sublayer of the OSI stack, initially defined three physical layers: frequency-hopped spread spectrum (FHSS), direct-sequence spread spectrum (DSSS), and infrared (IR), with a maximum data transmission rate of 2 Mbps. DSSS and FHSS operate in the unlicensed ISM band (2.4 GHz).[1][2]

In 1999, the 802.11 standard introduced the distributed coordination function (DCF) access method, designed for data and web applications but not suitable for QoS-intensive applications like voice and video. To address this limitation, the IEEE 802.11e amendment was standardized in 2005, replacing DCF with Enhanced Distributed Channel Access (EDCA). EDCA introduced service differentiation through four access categories (AC), each with its own access parameters: Arbitration Inter Frame Spacing (AIFS), Contention Window (CW), and Transmission Opportunity Limit (TXOPLimit). These parameters can be adjusted to prioritize different access categories based on QoS requirements.[3]

The introduction of 802.11e EDCA improved the performance of 802.11 networks by providing better protocol behaviors for applications with QoS constraints. However, when the network becomes congested, EDCA cannot guarantee QoS. Several evaluation studies have highlighted this limitation, leading to various proposals for improving QoS in wireless networks.

## **2 The issue:**

Wireless Local Area Networks (WLANs) have been very successful in recent years because of their simplicity, speed and low deployment cost. Therefore, they are a serious alternative to wired local area networks. They are beginning to be found everywhere: in airports, hotels, offices, and in domestic settings. At the same time, multimedia applications have seen explosive growth. The People must now receive high speed video, audio, voice and web services even when they are traveling in offices or on campuses. Although IEEE 802.11 has become popular due to its low cost and the Easy deployment, it does not provide quality of service (QoS) support. QoS is refers to the ability of a network to provide certain coherent services for 12 transmission data and is measured in terms of qualitative characteristics such as throughput, delay, and packet loss, which describe the quality of data traffic over the IEEE 802.11 network was unable to provide the performance that this type required of applications this inability of the MAC 802.11 mechanism to provide QoS support a has been an obstacle to the adaptation of modern multimedia applications in WLAN 802.11. To solve this problem, the IEEE 802.11 committee formed the committee Working Group E (802.11e) to define improvements to MAC 802.11 original.

## **3 Objective of the project:**

The objective of this project is:

1. Conduct an in depth study of the mechanisms used to support quality of service in IEEE 802.11e and its enhanced variants.
2. The impact of important parameters of the EDCA, , will be evaluated on the performance of the QoS suggested in IEEE 802.11e. Our goal is to see that if we change The environment like the time and the size of the data will the protocol show the same result ,
3. A comparative study of IEEE802.11e and the IEEE simple standard 802.11 will be conducted to assess WLAN performance.

To achieve this goal we are:

- As a first step in our research, we are conducting a detailed study of the standard IEEE 802.11 and its access mechanisms. We will discuss their limitations, which are the basis of the appearance of the EDCA mechanism at the advent to 802.11e.
- To identify the QoS metrics to be adopted in admission control, we let's choose the transmission delay and the achievable rate. What interests us in this thesis is the performance of the EDCA access mechanism only. In other words, we seek to identify the attainable time and throughput that result from the application of the EDCA access method.
- We will study the performance of the IEEE 802.11e by varying the priority settings using the NS3 simulator, then we will perform a comparison of simulation results with those of 802.11.

## **4 Contributions:**

Our contribution to this paper is to study and evaluate the performance of the IEEE 802.11e protocol. To do this we carry out a detailed study of the protocol IEEE 802.11 and the state of the art in relation thereto Chapter 2 provides an overview IEEE 802.11.

In order to ensure that QoS support is available and system performance is improved in WLANs, we affirm that it is important to search the domain of distributed channel access techniques that take into account QoS requirements. This research focuses on the MAC layer enhancements of the 802.11e EDCA feature.

Our approach is to start by studying the impact of the EDCA parameters important, such as CWmin, CWmax respectively, on the performance of the EDCA function QoS mechanisms (EDCF).

## **5 plan of the manuscript:**

To detail all our contributions and our working approach, this manuscript This thesis is organized as follows:

Following this introductory chapter1 aims to present a study of prior art covering 802.11. Thus, we describe the specifications of basic access mechanisms in 802.11, and then we discuss the limitations of QoS of these

mechanisms and proposals for improving their performance. We will see some IEEE802.11e protocols meaning the versions that are presented to the world and the difference between them and what makes every version what it is, for example some history and quality of that protocol. Then describe the specifications of the access mechanisms of the 802.11e QoS. We are particularly interested in the method of EDCA access point.

Chapter 2 provides an overview of the NS3 simulation tool, and describes the simulation scenario used for differentiation by two EDCA parameters. This chapter also provides an analysis of the simulation results.

After that deals with the comparison of performance between IEEE standards Simple 802.11e and IEEE 802.11, to demonstrate the effectiveness of the EDCA over DCF.

The brief concludes with a general conclusion summarizing the context of research of our study, the approach followed, our contributions and sets out a set of prospects.

# CHAPTER 1 :IEEE802.11 AND IEEE802.11e

## **1.1 Introductions:**

IEEE 802.11 Wireless LAN (WLAN) is a widely deployed wireless network technology that offers users the convenience of easy connectivity without the need for cables. However, the standard has limitations in providing Quality of Service (QoS). To overcome this, IEEE developed a variant called 802.11e, which focuses on guaranteeing QoS at the MAC layer.

In subsequent chapters, the new 802.11e variant and its mechanisms for providing QoS will be presented. This standard is a significant step towards integrating QoS support in WLANs, specifically enabling applications like voice over IP. Additionally, the IEEE 802.11 power-save mode (PSM) is crucial for devices with limited battery life, such as cellular phones, to ensure reasonable battery duration.

However, the combined performance of QoS and power-saving mechanisms is uncertain and requires further study. Analyzing the interaction between 802.11 PSM and 802.11e QoS mechanisms is necessary to determine if the desired QoS is maintained, identify potential conflicts, and quantify the impact of PSM on the efficiency of 802.11e QoS and overall system performance. Simulations can be employed to evaluate and gain insights into these aspects.

## **1.2 IEEE 802.11 Overview:**

The IEEE published 802.11 Wireless Local Area Network (WLAN) [3] in 1997. This standard belongs to the group of popular IEEE 802.x standards, e.g. IEEE 802.3 CSMA / CD [4]. IEEE 802.11 defines specifications for Media Access Layers Control (MAC) and Physical (PHY) for wireless LANs.

The standard comprises three PHY layers, which are an infrared (IR) baseband PHY; one frequency hopping spread spectrum (FHSS) radio and one spread spectrum radio in direct sequence (DSSS). These integer choices support PHY 1 and 2 Mbps. In 1999, the IEEE defined two high rates:



802.11b in the 2.4 GHz to 11 band Mbps, based on DSSS technology; and 802.11a in the 5 GHz to 54 Mbps band, based on orthogonal frequency division multiplexing (OFDM) technology. Recently, the 802.11g was finalized to be an extension of the 802.11b with 54 Mbps in the 2,4 GHz band [5].

IEEE 802.11 has gained popularity due to its profitability and is considered to be one of the most widely deployed wireless network technologies in the world. IEEE 802.11 defines two middle access coordination functions, the basic distributed coordination (DCF) and the optional point coordination function (PCF) (IEEE 802.11 WG, 1999). IEEE 802.11 defines two modes: ad-hoc mode and the infrastructure mode. The first mode forms an independent BSS (IBSS) where the STAs can communicate directly with each other using only the DCF, with no connectivity to any wired backbone. In the second mode, the STA communicates with the wired backbone via the access point bridge (AP), which can Use both DCF and PCF.

The 802.11 MAC layer can use two modes of operation: Distributed Coordination Function (DCF) and Point Coordination Function (PCF) DCF is a mode which can be used by all mobiles, and which allows equitable access to the radio channel without centralizing access management (fully distributed). This mode can be used when there are no base stations (ad hoc mode) as well as when there is one (infrastructure mode), PCF is a mode in which the base stations are responsible for managing access to the channel in their coverage area for mobile units attached to them [6].

In the next chapters, DCF is discussed in more detail because it is the basis for access to Distributed Channel Enhanced (EDCA) introduced in IEEE 802.11e.

## **1.3 basic IEEE 802.11 versions:**

### **1.3.1 very Slow (1997) :**

The first 802.11 specification included two spread spectrum methods in the unlicensed 2.4 GHz band 1Mbps frequency hopping (FHSS) and 1 and 2 mbps direct sequence (dsss).

### **1.3.2 slow Speed (1999) :**

Its name is 802.11b, Using Dss and the 2.4 GHz band this protocol boosted speed to 11 Mbps while retaining the slow DSSS modes to accommodate weak singles.

### **1.3.3 Medium Speed (1999) :**

Using orthogonal FDM (OFDM) , this version how called 802.11a transmit up to 54Mbps , it uses the 5 GHz band and is not compatible with 11b

### **1.3.4 Medium Speed (2003) :**

The 802.11g the name and it using orthogonal FDM (OFDM)transmission, the 11g increased speed in the 2,4 GHz band to 54 Mbps

### **1.3.5 Highest Speed (2019) :**

Is called the 802.11ax , is operates in both the 2,4 GHz and the 5 Ghz bands with data rates in the multi-gigabit range

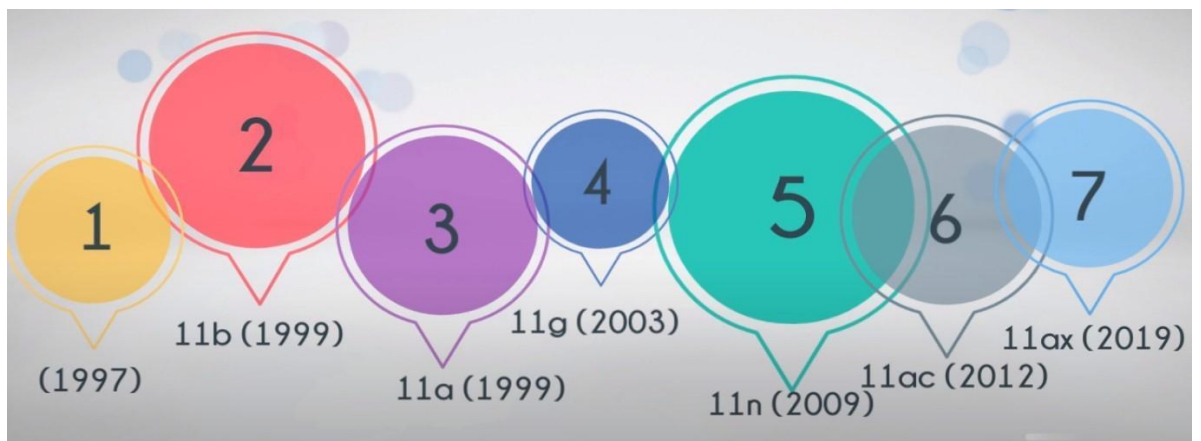


Figure 1.1 history of the versions [REF]

## **1.4 Distributed Coordination Function (DCF)**

The basic DCF access method uses the CSMA/CA (Carrier Multiple Access with Collision Avoidance). The latter operates as a listening before the conversation, i.e. the transmitting station transmits the signal and listening at the same time the channel. If the media is found inactive at least during the time of the DCF interframe space (DIFS), the station starts transmission and other stations are waiting for the media to return to idle for at least the DIFS time.

The destination station successfully receives a frame, it recognizes it by sending it back an ACK frame after a short period of inter-frame space (SIFS). Figure illustrates the mechanism.

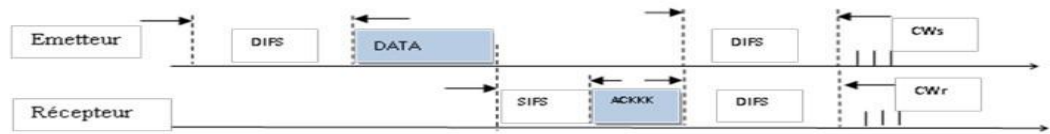


Figure 1.2 Mechanism of DCF

To ensure channel access operation, the DCF uses a set of intervals time called Inter Frame Spacing (IFS). As shown in Figure below

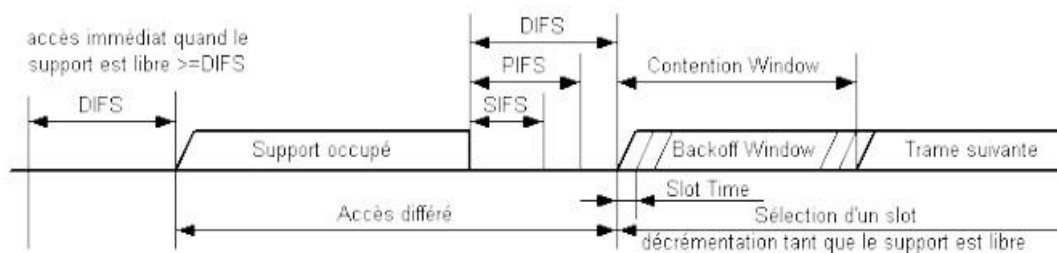


figure 1. 3 :relation between the space in the trams

PIFS is used by access points in the PCF (IEEE 802.11 access mechanism optional), where the access point (AP) centrally controls media access by interviewing individual stations. In PCF, the priority of the AP is greater than that of ordinary stations; it must therefore wait for PIFS instead of longer DIFS before sending frames.

SIFS is the shortest of IFS. SIFS is the time between data frame and frame ACK, as shown in Figure 2.2, so that it can prevent other stations from sending at the same time. The receiver sends an ACK frame because the other stations must wait for the DIFS time, which is longer than SIFS, before starting the transmission. Thus, in this way, the station transmitting the ACK frame has

priority over the station that attempts to transmit the data frame. IFS values are defined in slot time and depend on the underlying physical layer (PHY).

There are two types of carrier detection used to determine whether the carrier is idle or busy. By means of the physical carrier detection, the wireless channel can be detected at the physical layer itself. When using discovery of virtual carrier in the MAC layer, the station receiving the frame which is not to it directed; it will check the duration field in the frame header, which specifies the time 10 required to send the frame and receive the ACK in response, then postpone access to the support for this particular time period.

### **1.4.1 Collision avoidance and interruption procedure:**

A collision occurs if two or more stations detect average idling and attempt to transmit simultaneously. To avoid such collisions, the station must wait for another time before transmitting if the medium is detected busy during the period DIFS or, if the media was busy just before the station started waiting for the DIFS period. In these cases, the station will delay access until the media becomes idle, then selects a random interrupt value, which specifies the period of time in units of time slices; After the media has become inactive, the station must wait in addition to DIFS.

This additional random delay in the form of a decrease makes it possible to avoid the collisions. Otherwise, once the media becomes idle during DIFS, all stations are trying to transmit. This mechanism is called collision avoidance (CA) and the entire access mechanism is called CSMA/CA.

Carrier detection with collision avoidance is used in wireless networks instead of using collision detection (CSMA/CD) in cable networks, like IEEE 802.3 Ethernet [4], due to the lack of collision detection in the wireless networks. In a wired network, the transceiver has the capability of receiving and sending simultaneously, so it can detect collisions, but in a wireless network, the stations do not have the capacity to operate simultaneously.

After selecting the Back off value, since the media has been detected as being inactive during the period of time DIFS, the station started decrementing its interrupt timer for each interval of time. If the media becomes busy during this

interruption, the station will suspend its interrupt timer. Once the media is idle again for DIFS, the return timer resumes. When the Interrupt Timer Reaches zero, the station is authorized to transmit.

Although the station must choose a new random interrupt value, the first station that has attempted will continue to count down its interrupt timer instead of selecting a new interrupt timer. Therefore, in this way, the station that tries first and waits longer is better than the station who tries later, because she'll only wait for her rest time.

Randomly select a random interrupt value in the range from 0 to collision window  $[0, CW]$  and set  $CW$  to the minimum collision window size  $CW_{min}$  on first transmission attempt. After each transmission unsuccessful (collision), use equation 2.1 to double the  $CW$  and increase it by exponentially until the maximum collision window size  $CW_{max}$  is affected. The values of  $CW_{min}$  and  $CW_{max}$  depend on the physical layer of base (PHY).

For the OFDM physical layer, the values are respectively 15 and 1023. In this case, the size of the collision window increases in the form of 15, 31, 63, 127, 255, 511, 1023. Therefore, this mechanism is also called an interrupt exponential.

If the sender does not receive the ACK frame within the specified ACK delay, it is determined transmission is unsuccessful (collision). After the delay period ACK, the station assumes that a collision has occurred, waits for the media to be idle for DIFS, and then goes back into a back off with a size doubled by  $CW$ , this reduces the probability of collision in case there are several stations attempting to access the canal.

DCF defines a limited number of retransmission attempts which is the number of times that a frame can be retransmitted. If it is determined that the transmission is unsuccessful after reaching the retransmission limit, the frame will be dropped.

After each successful transmission, the transmitting station performs another back off (the size  $CW$  is reset to  $CW_{min}$ ) called the post-back off, even if it has no frame to be transmitted. The latter guarantees at least a back off period

between two successive transmissions, and it allows the other stations to decrement their back offs and access support.

If the back off timers for two or more stations reach zero at the same time, or if two or more stations accidentally get the same Interrupt values. This indicates that the probability of collision is inversely proportional to the size of the CW, i.e. if the size of the CW is smaller, the higher collision rate and vice versa.

## **1.5 Limitations de IEEE 802.11 :**

### **1.5.1 Quality of Service:**

Quality of service (QoS) is the ability to transport a given type of traffic under good conditions, in terms of availability, throughput, time delay, good conditions, a given type of traffic, in terms of availability, throughput, transmission, jitter, packet loss rate [7]. Applied to switched networks of packets (router-based networks) QoS refers to the ability to be able to guarantee an acceptable level of packet loss, defined contractually, for a given purpose (Voice over IP, video conferencing, etc.) [8] .

### **1.5.2 quality of service parameters:**

The QoS requirements can be classified into three main dimensions: the band bandwidth, delay, and data loss [12]. Table 2.1 presents these dimensions.

#### **A. Bandwidth:**

This is the amount of data that can be transmitted over a period of time. Most often, it is measured in bits/second (bits per second, bps) where one of its orders of magnitude: kilobits per second or Kbps (10<sup>3</sup> bps), megabits per second or Mbps (10<sup>3</sup> Kbps), gigabits per second or Gbps (10<sup>3</sup>Mbps), etc. Bandwidth is a key parameter of data speed: the more bandwidth is higher, the faster a file is transmitted. This parameter is also crucial for real-time applications. For example, live video requires a tape floor passageway under which one must not descend to guarantee a transmission of real-time images. The bandwidth constraint is therefore a threshold value of the available bandwidth under which you should not drop [9].

## **B. Delay:**

It is the time between sending a data packet and arriving at its destination. It is measured in seconds where one of its orders of magnitude (of a few milliseconds) for transmissions requiring a very high reactivity to several minutes for time-tolerant applications). A delay constraint defines a maximum time not to exceed for all packages. Real-time and interactive applications are very sensitive to the delay.[9] Significant delays severely undermine the performance of a lot of applications.

## **C. Data loss:**

It characterizes the delay between the transmission and the reception of a packet. Most multimedia applications are classified as bandwidth and delay sensitive because they require strict bandwidth and delay guarantees, but are generally tolerant to losses because they can tolerate some amount of data loss. Data loss in these applications results in a quality of slightly reduced output, but can be neglected to some extent. The effects of such losses of data on the quality of the application and the amount of tolerable losses depend on the application and coding scheme used [6]. On the other hand, data-driven applications such as file transfer and mail electronics are considered loss sensitive. They can tolerate delays and bandwidth variations but require reliable data transfer.

**Table 1.1: Application QoS Performance Dimension**

<b>Performance Dimensions</b>			
<b>Application</b>	<b>Sensibility of :</b>		
	<b>Bandwidth</b>	<b>delay</b>	<b>Data lost</b>
<b>VoIP</b>	<b>Low</b>	<b>High</b>	<b>Medium</b>
<b>Video conference</b>	<b>High</b>	<b>High</b>	<b>Medium</b>
<b>Transaction client /server</b>	<b>Medium</b>	<b>Medium</b>	<b>High</b>
<b>E- mail</b>	<b>Low</b>	<b>Low</b>	<b>High</b>
<b>Transfer of file</b>	<b>Medium</b>	<b>Low</b>	<b>High</b>

### **1.5.3 Qos DcF limitations:**

IEEE 802.11 is based on the best possible service, DCF has no warranty to support QoS; in fact, it does not guarantee bandwidth, delay and loss of data [10]. All data traffic is handled by a policy FIFO First In First Out in a better effort way.

All STAs in the BSS dispute for wireless support with the same priority. This results in the asymmetrical flow rate between the uplink and the down link, because the AP has the same priority as the other ATs but with a lot of high demands throughput. Also, there is no differentiation between data streams to support the traffic with QoS requirements.

As the number of STAs in a BSS increases, the probability of collisions becomes higher and has as a consequence frequent retransmissions. Therefore, the QoS decreases as the overall throughput in the BSS. This lack of guarantees is a major one limiting the provision of QoS services for multimedia applications in 802.11 networks [6].

### **1.6 The IEEE 802.11 .e :**

All these limitations for DCF have led to a large number of research activities to improve QoS support. In 2005, the IEEE published a new standard called IEEE 802.11e [3], which is an amendment to IEEE 802.11 that introduces improvements in QoS.

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 of channel access, similar to those defined in the legacy 802.11 MAC: HCF Controlled Channel Access (HCCA) and Enhanced Distributed Channel Access (EDCA). Both EDCA and HCCA define Traffic Categories (TC). For example, emails could be assigned to a low priority class, and Voice over Wireless LAN (VoWLAN) could be assigned to a high priority class.[28]

IEEE 802.11e supports QoS by introducing a priority mechanism. It supports differentiation of services by affecting data traffic with different priorities based on their QoS requirements.



Four different Access Categories (ACs) have been defined for data of a different priority. Access to support is granted on the basis of priority data traffic, so that each frame with a particular priority is mapped to a CA, and service differentiation is obtained using different sets of conflict settings for each CA to fight for support. In IEEE 802.11e, the STA that provides QoS services is called the QSTA (QoS Station). ; The major enhancement of 802.11e:

1. Hybrid Coordination Function (HCF) w two components
  - . Contention Free Access: Hybrid Polling
  - . Contention-based Access: Enhanced DCF (EDCF)
2. Direct Link: Traffic sent directly between two stations
3. Frame bursting and Group Acknowledge
4. Automatic Power Save Delivery

### **1.6.1 MAC architecture and frame**

#### **A. architecture of MAC:**

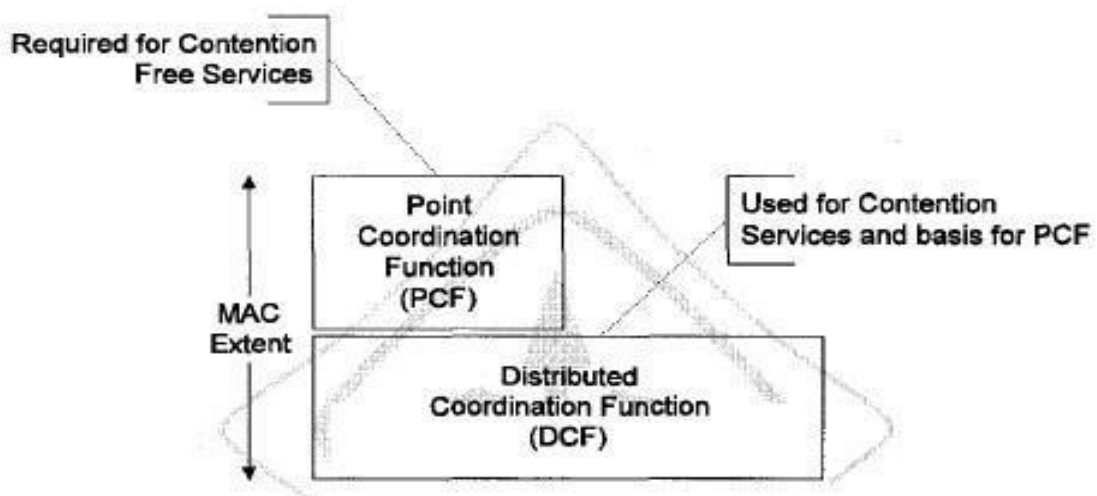


figure 1.4 IEEE 802.11 MAC Architecture[27]

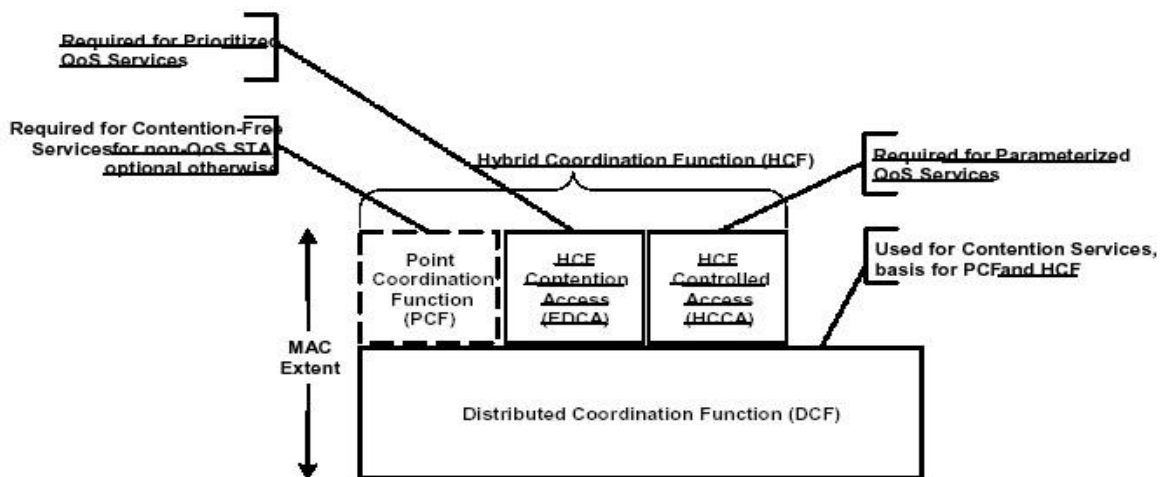


Figure 1.5 IEEE 802.11e MAC Architecture[27]

\_DCF : A contention-based access for 802.11.

\_PCF : An option to support contention-free access in 802.11.

\_Hybrid Coordination Function (HCF): IEEE 802.11 Task Group E (TGe) proposes HCF to provide QoS for real-time applications.

### B. MAC frame :

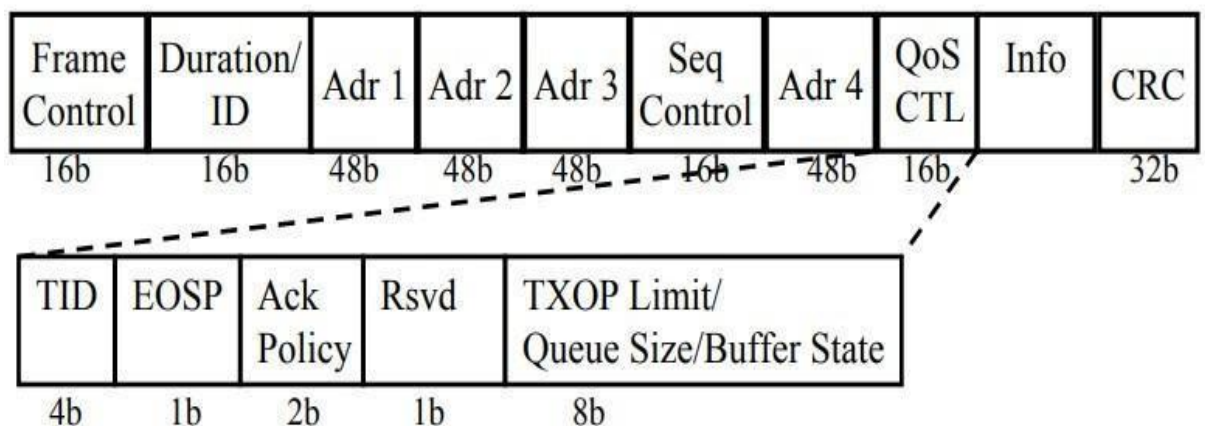


Figure 1.6 IEEE 802.11e QoS Field IEEE 802.11e QoS Field [27]

- A QoS field was introduced in MAC Frames by 802.11e.
- TID: Traffic identifier. Traffic category of the MSDU (0-7) or per-negotiated traffic spec number (8-15)

- EOSP (End of Service Period): In U-APSD mode, upon receiving a frame from a power save station, AP sends “maxSP” frames to the station. EOSP is set only in the last frame, clear in other frames. More bit as usual indicates if there are more frames in this or next service period.

### **1.6.2 Hybrid Coordination Function (HCF) :**

HCF combines functions from the DCF and PCF with enhanced QoS-specific mechanisms.

HCF consists of

- \_ Enhance DCF (EDCF) for contention-based access
- \_ Controlled Access (HCCA) for contention-free access

#### **A. Enhanced DCF (EDCF) :**

With EDCA, high-priority traffic has a higher chance of being sent than low-priority traffic: a station with high priority traffic waits a little less before it sends its packet, on average, than a station with low priority traffic. This is accomplished through the TCMA protocol, which is a variation of CSMA/CA using a shorter arbitration inter-frame space (AIFS) for higher priority packets.[19] The exact values depend on the physical layer that is used to transmit the data. In addition, EDCA provides contention-free access to the channel for a period called a Transmit Opportunity (TXOP). A TXOP is a bounded time interval during which a station can send as many frames as possible (as long as the duration of the transmissions does not extend beyond the maximum duration of the TXOP). 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 inordinate 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 (MSDU) or MAC management protocol data unit (MMPDU).

The levels of priority in EDCA are called access categories (ACs). The contention window (CW) can be set according to the traffic expected in each access category, with a wider window needed for categories with heavier traffic. The CWmin and CWmax values are calculated from aCWmin and aCWmax

values, respectively, that are defined for each physical layer supported by 802.11e.

#### **a. EDCA work:**

EDCA is based on the concept of “Access Categories” (ACs) and its entities independent of back off. The QoS (QSTA) station implements four ACs. Each CA has a set of associated EDCA parameters. These settings include space arbitration between frames (AIFS), contention window (CW) and their values respective minimum and maximum CW<sub>min</sub> and CW<sub>max</sub>.

Each CA of each station competes with other CAs to obtain an opportunity for transmission (TXOP). To do this, it will independently start an outage timer after detecting channel idle during interval AIFS.

The back off period of each AC is selected based on the uniform distribution over [0, CW [AC]]. A CW<sub>min</sub> value was initially assigned to the size CW, and it will be doubled when the transmission has failed up to Cw<sub>max</sub>. Plus the CW<sub>min</sub> [AC] is small, plus the channel access time of the corresponding priority is short, so for a given traffic condition, there is a better chance to access the media. Depending on each type of traffic generated (including audio, video and text), traffic from an application is associated with certain QoS.

#### **b. Categories accord's (AC) :**

Enhanced Distributed Channel Access (EDCA), which defines four categories of access to channels or priorities:

- a priority to the voice.
- a priority to video.
- a “Best Effort” priority for standard applications.
- a priority called "background" when the traffic is low.

Each frame of the upper layer arrives at the MAC layer with a value of priority. A total of eight levels of user priority are distinguished or UP) ranging from 0 to 7. The relationship between UPs and ACs is shown in the Table below.

Priorité	UP	AC	Désignation
Plus basse ↓ Plus haute	1	AC_BK	Background
	2	AC_BK	Background
	0	AC_BE	Best Effort
	3	AC_BE	Best Effort
	4	AC_VI	Vidéo
	5	AC_VI	Vidéo
	6	AC_VO	Voix
	7	AC_VO	Voix

Table 1.2 Relationship between priorities and access categories in EDCA[27]

Each QSTA implements four transmit queues, one for each AC and four independent functions (EDCAF), one for each queue, such as the shows figure below

EDCAF represents an enhanced version of the DCF access method, by introducing service differentiation; differentiating access to support through the Principle of priorities where each priority is associated with the corresponding CA.

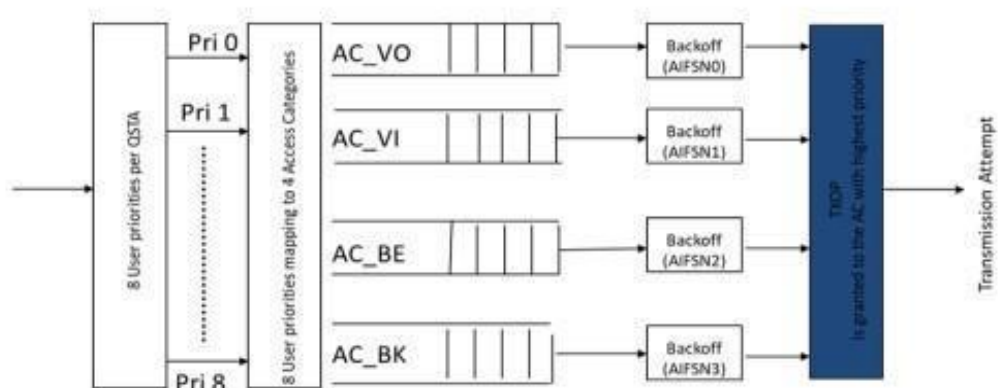


Figure 1.7 : Four ACs, each with its own queue and EDCA parameters[27]

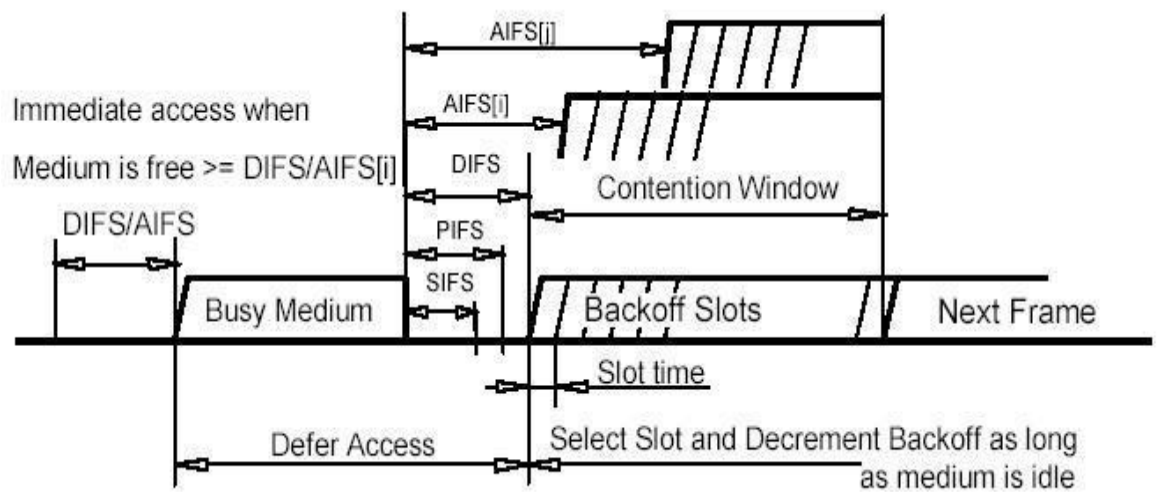


Figure 1.8 : IFS plan[27]

### **c. EDCA settings :**

Basically, the main difference between DCF and EDCAF is that EDCAF uses specific parameter values for each AIFS AC [AC], CWmin [AC] and CWmax [AC], while DCF uses fixed values DIFS, CWmin and CWmax. In what follows, each EDCA parameter and its contribution to the differentiation of the services are briefly described.

#### **c.1 AIFS**

(Arbitration Interframe Space): The minimum period during which the medium must be detected at rest before QSTA starts transmission, or the interruption. This is a variable value and depends on AC. To ensure the right Differentiation, instead of using a fixed DIFS value, an AIFS is applied for each CA using the following equation:

$$\mathbf{AIFS = a SIFSTime + AIFSN \times a SlotTime.....(1) [27]}$$

AIFSN is a number determined for each AC, specific for the AIFS parameter, Slot Time is the duration of a time slot. The minimum value of AIFSN is 2 and its maximum value is 15. High priority CAs use AIFSN values smaller than low priority CAs. Table shows the AIFSN values by defect for all four Cas.

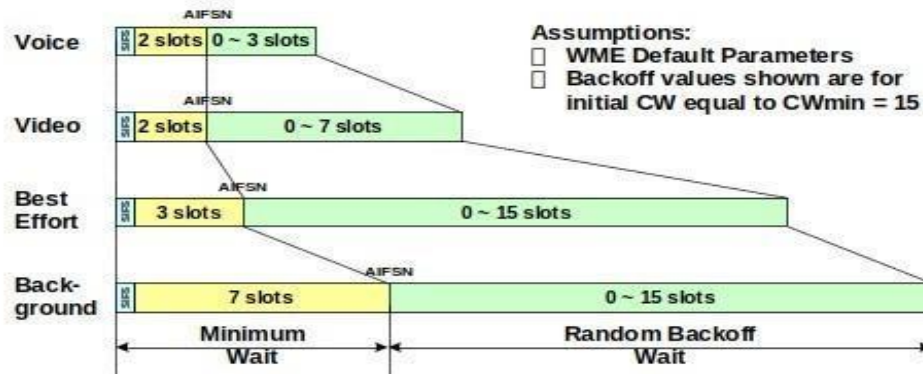


Figure 1.9:AIFS-based traffic priority[27]

The figure shows how to assign transmission priority to different CAs by function of the AIFS period. For higher priority CAs, an AIFSN plus small forces their CFDEs to wait a shorter time before they can start

the transmission or the countdown of its interrupt timer with respect to EDCAF for low priority CA. This will ensure that higher priority CAs have a greater bandwidth. In addition, the shorter AIFS length ensures that Higher priority CAs will not experience longer delays, which is a requirement critical for delay-sensitive applications, as described above.

### c.2 CWmin and CWmax:

The minimum and maximum limits of the collision window depend on CA. The higher priority ACs have standard values CWmin and Smaller CWmax while lower priority CAs have higher values big. Table of Values standard of parametrizes EDCA shows the standard values of the parameters CWmin and CWmax of the four CAs. Table under it lists the parameters aCWmin and aCWmax specific to the OFDM and DSSS physical layers.

Table 1.3 parameter of OFDM DSSS

Parameter	OFDM	DSSS
ACWmin	15	31
aCWmax	1023	1023

Table above shows the standard values of the CW parameters for different ACs. One small CW of AC will cause its EDCAF to choose a small random backoff value, which will result in a shorter period of time in addition to the AIFS when the media will become inactive. It gives CA a higher priority than CA with a CW greater, which results in a greater back off value and a delay of longer delay.

Table 1.4 Values standard des parametrizes EDCA

AC	Cwmin	Cwmax	AIFSN	TXOP(ms)
AC_VO	$(aCWmin+1)/4 - 1$	$(aCWmin+1)/2 - 1$	2	1.504
AC_VI	$(aCWmin+1)/2 - 1$	aCWmin	2	3.008
AC_BE	aCWmin	aCWmax	3	0
AC_BK	aCWmin	aCWmax	7	0

### **c.3 TXOP (Transmission Opportunity):**

The TXOP limit is the period of time that EDCAF can transmit after accessing the medium. When EDCAF gets TXOP, as long as the transmission time does not exceed the TXOP limit, it can start transmitting frames. This transmission limit covers the entire frame exchange sequence, including SIFS periods and acknowledgments (ACKs).

The EDCA Standard Values table shows the default TXOP limit values for different ACs. None Null value of TXOP limits indicates that the EDCAF can transmit multiple frames in a transmission opportunity, so that the transmission time does not exceed not the TXOP limit. This is called unrestrained bursting (UBC). The consecutive frame transmissions in a transmission opportunity are separated by SIFS time periods.

As shown in the Table above each CA has its own parameters and own EDCA Function (EDCAF) behavior, higher priority CAs (voice) and video) expect a short



period of AIFS, while lower priority CAs (for background and best effort) should wait a longer period of AIFS before to access the support. The size of the CW is different, so CA has a higher priority and will select the back off value from the smaller CW instead of the CA with a lower priority.

The last TXOPLimit differentiation parameter increases the throughput of ACs, therefore, it is useful to have a large value for this setting for applications bandwidth-hungry. This justifies coarsely the faculty TXOPLimit of the standard in Table below or AC\_VI which 25 requires a significant portion of the band Passing is assigned the highest value of TXOPLimit.

Basically, for high priority CAs, AIFS, CWmin, and CWmax have smaller values, while the TXOP limit has larger values. The values of the EDCA parameters are sometimes call AIFS [AC], CWmin [AC], CWmax [AC] and TXOP Limit [AC].

### **C. Contention Free Access: Hybrid Polling(HCCA) :**

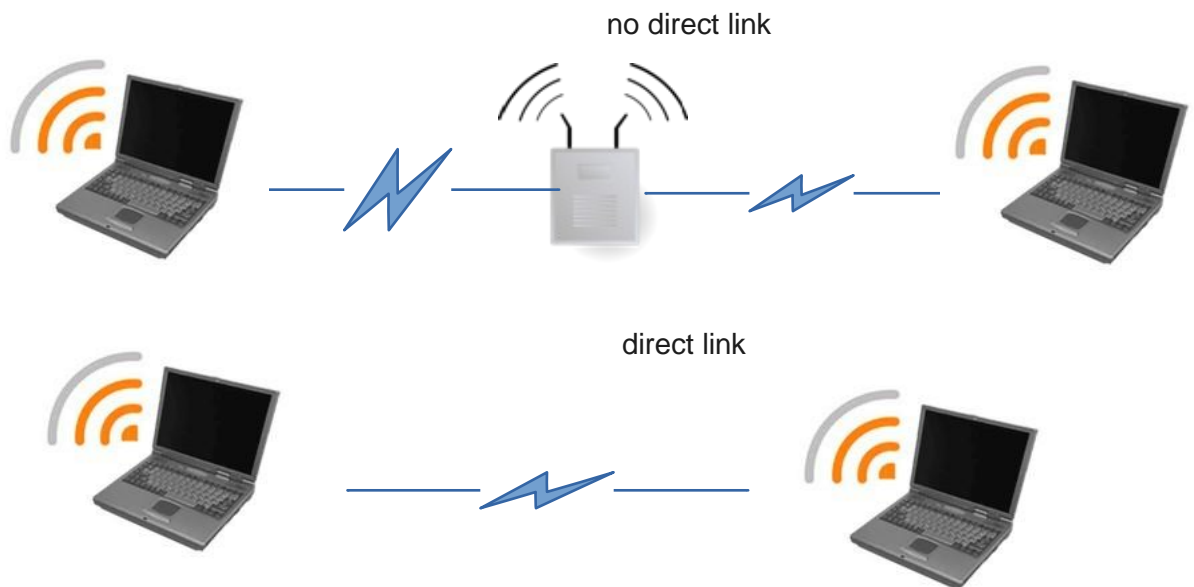
The HCF (hybrid coordination function) controlled channel access (HCCA) works a lot like PCF. However, in contrast to PCF, in which the interval between two beacon frames is divided into two periods of CFP and CP, the HCCA allows for CFPs being initiated at almost any time during a CP. This kind of CFP 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 Traffic Class (TC). The HC can use this info to give priority to one station over another, or better adjust its scheduling mechanism. Another difference is that stations are given a TXOP: they may send

multiple packets in a row, for a given time period selected by the HC. During the CFP, 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

### **1.6.3 Direct Link :**

Any station can transmit to any other station in the same BSS NO need to go through AP (access point) like this figure shows ;



**Figure10 Direct link**

### **1.6.4 Frame bursting and Group Acknowledge :**

#### **A. frame bursting**

- EDCF parameters announced by access point in beacon frames
- Cannot overbook higher priorities
- Need admission control
- EDCF allows multiple frame transmission
- Max time = Transmission Opportunity (TXOP)

- Voice/gaming has high priority but small burst size
- Video/audio has lower priority but large burst size

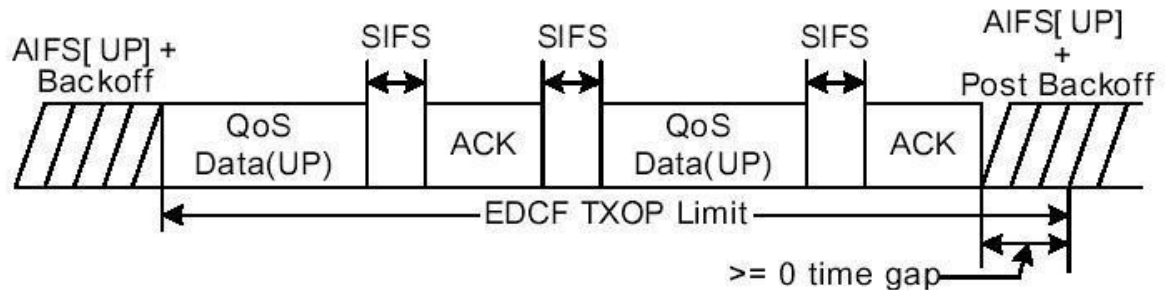


figure 1.11: frame bursting[27]

## B. Group Acknowledge:

The Group Acknowledgement mechanism improves the channel efficiency by allowing a group of QoS Data MPDUs to be transmitted, each separated by a SIFS period, and aggregating several acknowledgments into ONE frame.

Two types of Group ACK mechanisms:

- \_ *immediate*: for high-bandwidth, low latency traffic
- \_ *delayed*: for applications that can tolerate moderate latency.

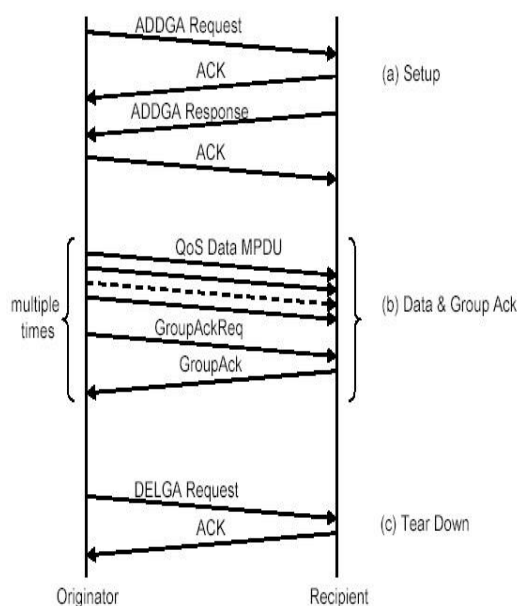


figure 1.12 Message sequence [27]

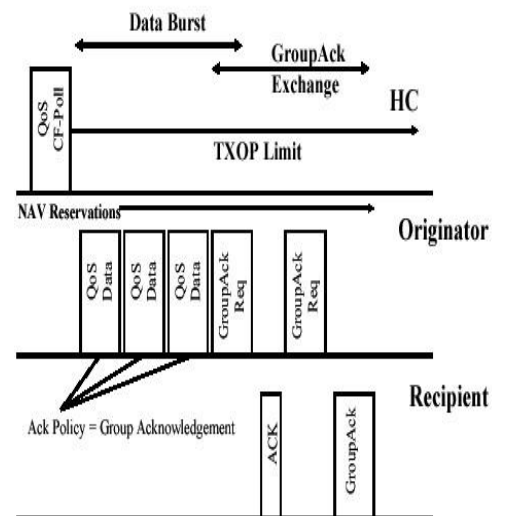


figure 1.13 An example of **immediate** group ack

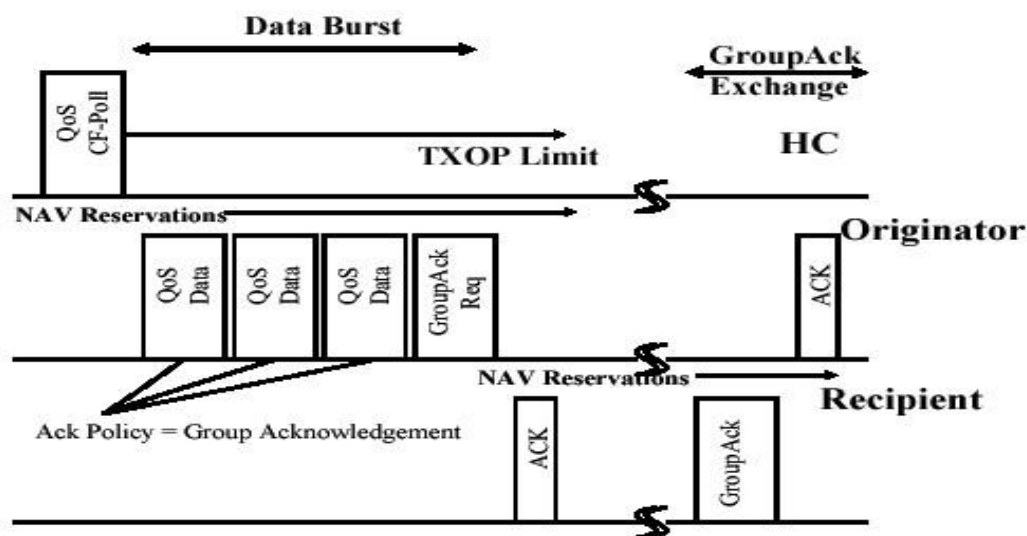


Figure 1.14 delayed group ack[27]

## 1.6.5 Automatic Power Save Delivery (APSD)

In addition to the Power Save Polling mechanism, which was available pre-802.11e, new power save delivery and notification mechanisms have been introduced in 802.11e. APSD (automatic power save delivery) provides two ways to start delivery: 'scheduled APSD' (S-APSD) and 'unscheduled APSD' (U-APSD). With APSD, multiple frames may be transmitted together by the access point to a power-saving device during a service period. After the end of a service period, the device enters a doze state until the next service period. With S-APSD, service periods start according to a predetermined schedule known to the power-saving device, thus allowing the Access Point to transmit its buffered traffic without the need for any signaling. With U-APSD, whenever a frame is sent to the Access Point, a service period is triggered, which allows the access point to send buffered frames in the other direction. U-APSD can take a 'full' U-APSD or 'hybrid' U-APSD form. With Full U-APSD, all types of frames use U-APSD independently of their priority. With Hybrid U-APSD, either U-APSD or the legacy Power Save Polling mechanism is used, depending on the access category. S-APSD is available for both channel access mechanisms, EDCA and HCCA, while U-APSD is available only for EDCA[21][22]

APSD is a more efficient power management method than legacy 802.11 Power Save Polling, leading to lower power consumption, as it reduces both the signaling traffic that would otherwise be needed for delivery of buffered frames to power-saving devices by an AP and the collision rate among power-save polls, typically transmitted immediately after the beacon TIM. S-APSD is more efficient than U-APSD because scheduled service periods reduce contention and because transmission between the access point and a power-saving device starts without the need for any signaling. A power-saving device using U-APSD must generate signaling frames to retrieve buffered traffic in the absence of uplink traffic, as for instance in the case of audio, video, or best effort traffic applications found in today's smartphones. U-APSD is attractive for VoIP phones, as data rates are roughly the same in both directions, thus requiring no extra signaling—an up link voice frame can trigger a service period for the transmission of a down link voice frame [23]

➤ **Unscheduled APSD (U-APSD):**

- AP announces waiting frames in the beacon □ When stations wake-up they listen to the beacon.
- Send a polling frame to AP.
- AP sends frames.

➤ **Scheduled APSD (S-APSD):**

- Station tells AP it's wake up schedule
- AP sends frames on schedule. No need for polling.
- Pre-802.11e: AP announces in Beacon. STA polls. AP sends one frame with more bits. STA polls. AP sends the next frame...

## **1.7 conclusion**

In this chapter we introduce the protocol that we study after that we did see what the enhanced tool in it , first we did see the architect of it and how the frame of the mac look like with the tool that the protocol put the we did se most the place that enhanced like the DCF and more

This chapter provided details on the EDCA and its important QoS parameters. such as: AIFS: the period of time during which the support must be inactive before the start of the transmission or back off is started; CWmin, CWmax: size (in the time intervals) of the contention window used for back off; TXOP Limit: maximum transmission time after media is taken. The next chapter cover simulation studies, the tool used and simulation parameters And the priority

# CHAPTER 2 :SIMULATON AND COMPARESON

## **2.1 Introduction:**

Simulation allows the user to define a network and simulate communications between the nodes of this network, to test the new protocols, anticipate problems that may arise in the future, and Implement the technology that best meets your needs.

To study and evaluate the performance of the 802.11e standard, we use a simulator, since actual tests are so expensive a lot of simulators are created to do this job such as OPNET, OMNET, NS2, NS3, J-SIM. And we chose the software NS3.

## **2.2 NS3 Simulator Overview:**

ns-3 is a discrete-event network simulator, targeted primarily for research and educational use. ns-3 is free software, licensed under the GNU GPLv2 license, and is publicly available for research, development, and use.

The goal of the ns-3 project is to develop a free and open source simulation environment suitable for networking research: it should be aligned with the simulation needs of modern networking research and should encourage community contribution, peer review, and validation of the software. ns-3 is maintained by a worldwide team of volunteer maintainers. [24]

### **2.2.1 Getting started with installing ns-3**

There are many network simulation tools available as open source and proprietary solutions. In Comparison to ns-2 and other simulation tools, ns-3 offers the following features [26]

- The primary changes ns-2 users observe with ns-3 is the scripting language. Also, ns-3 support is limited to simple wired and Wi-Fi network simulation only.
- ns-3 programs are written in Object-oriented Tool Command Language (OTcl), whereas ns-3 programs are written in C++ or Python.
- ns-3 is open source software and has excellent support from the ns-3 team.

- ns-3 is designed as a set of modules (internet, Wi-Fi, LTE, etc.) and users can extend existing modules and add new modules.
- ns-3 is designed to be used in the command line as well as visualization mode.
- ns-3 can be easily extended with data analysis and visualization tools.

In this section, you will start with the first hands-on task, which is installing ns-3 successfully. Let's start by installing all necessary dependencies for ns-3: [26]

1. Install the core dependencies for ns-3 build essentials and compilation packages: ns-3 can be used on Linux, macOS, or Microsoft Windows operating systems.

```
sudo apt-get update  
sudo apt install build-essential libsqlite3-dev libboost-all-dev libssl-dev git python3-setuptools castxml
```

2. Install the Python dependencies for ns-3 Python bindings:

```
sudo apt install gir1.2-goocanvas-2.0 gir1.2-gtk-3.0 libgirepository1.0-dev python-dev python3-gi python3-cairo python3-pip python3-graphviz python3-pygccxml
```

3. Install the dependencies for ns-3 features support, such as NetAnimator, gdb, and valgrind:

```
sudo apt install g++ pkg-config sqlite3 qt5-default mercurial ipython3 openmpi-bin openmpi-common openmpi doc libopenmpi-dev autoconf cvs bzip2 unrar gdb valgrind uncrustify doxygen graphviz imagemagick python3-sphinx dia tcpdump libxml2 libxml2-dev cmake libc6-dev libc6-dev-i386 libclang-6.0-dev llvm-6.0-dev automake
```

Next, download the latest ns-3 version and follow the steps for installing it:

```
$ wget -c https://www.nsnam.org/releases/ns-allinone-3.36.tar.bz2
```



4. Unzip or extract the downloaded file: **\$ tar -xvjf ns-allinone-3.36.tar.bz2 [26]**

5. Move to the following directory: **\$ cd ns-allinone-3.36/ns-3.36**

6. Next, configure the ns-3 modules using the build system. The ns3 command (available in the ns-allinone-3.36/ns-3.36 folder) makes use of a Python wrapper around CMake. It is similar to Waf in earlier ns-3 versions. The following command configures ns-3 modules with all example and test simulation programs: **\$ ./ns3 configure --enable-examples --enable-test[26]**

7. Next, build all the configured ns-3 modules using the following command. This command takes a while to complete: **\$ ./ns3 build**

8. After the successful build of ns-3, you have many example simulation programs ready to execute. Try running a first example simulation with the following command and observe the output: **\$ ./ns3 run first**

### **2.2.2 the way NS3 work:**

NS-3 (Network Simulator 3) is a discrete-event network simulator that is used to simulate and evaluate the performance of various network protocols and systems. It allows researchers and developers to model and analyze complex network scenarios and study the behavior of network protocols under different conditions.

Here's a high-level overview of how NS-3 works:

**1. Model Construction:** In NS-3, you construct your network simulation by creating objects that represent various components of the network such as nodes, channels, devices, protocols, applications, etc. You use helper classes and modules provided by NS-3 to simplify the creation and configuration of these objects.

**2. Event Scheduling:** NS-3 is a discrete-event simulator, which means that it advances the simulation time in discrete steps based on the occurrence of events. Events can be anything that affects the network behavior, such as packet transmissions, receptions, timeouts, or user-defined events. NS-3 maintains an

event queue that stores these events and schedules them based on their occurrence time.

**3.Event Execution:** NS-3 executes the events in the event queue in the order of their occurrence time. When an event is executed, it updates the network state and triggers subsequent events. For example, when a packet transmission event is executed, NS-3 updates the state of the transmitting and receiving devices, updates the channel state, and schedules events related to the packet reception.

**4.Time Advancement:** After executing an event, NS-3 advances the simulation time to the time of the next scheduled event. It repeats this process until there are no more events in the event queue or the simulation is terminated.

**5. During the simulation,** NS-3 can collect various performance metrics such as packet loss, delay, throughput, etc., for analysis. NS-3 provides tools and APIs to access and analyze these simulation results.

**6.Visualization:** NS-3 supports visualization of the simulated network using tools like NetAnim allows you to animate the network topology, visualize packet transmissions, and monitor the state of the network in real-time or post-simulation.

**7.Customization and Extension:** NS-3 is highly customized and extensible. You can create your own models, protocols, or applications by extending the existing NS-3 framework. NS-3 provides a modular and object-oriented architecture that allows you to plug in your own components and modify the behavior of existing components as needed.

By using NS-3, you can simulate a wide range of network scenarios, evaluate different protocols and algorithms, and analyze their performance in a controlled and repeatable environment.

## **2.3 Network Animator (Nam)**

NS-3 does not allow visualization of the results of the experimenter. It only allows storing a trace of the simulation so that it can be exploited by another software, like NAM. Nam is a Tcl/Tkbased animation tool used in NS to visualize network simulation plots and data plots. The theoretical model of the NAM was

not only created to read a large set of animation data, but also extensible enough to be used in any way the type of simulated network (fixed, mobile or mixed). Which allows you to visualize any type of possible situation.

## **A. installation of NAm**

NetAnim's Graphical User Interface (GUI) is implemented using Qt, a cross-platform software. In order to install the NetAnim GUI, execute the following commands:

- cd ns-allinone-3.36/netanim-3.108
- make clean
- qmake NetAnim.pro make

Follow these steps to visualize your simulation program execution using NetAnim:

1. Include the `[#include "ns3/netanim-module.h"]` header in your simulation program:

A. Include the following code: `AnimationInterface anim ("animation.xml");` before `Simulator::Run()` in your simulation program.

B. Execute the program using `./ns3 run scratch/your simulation program`. After successful execution, it generates an `animation.xml` file.

2. Now, you can open the `animation.xml` trace file using NetAnim to visualize your simulation.

Next, we explore NetAnim's various options for visualizing ns-3 simulations.

## **2.4 Impact of QoS Differentiation Parameters on EDCA**

### **performance:**

We will evaluate the impact QoS differentiation parameters

### **2.4.1 Scenario: customization of various parameters such as payload size, simulation time, and distance**

example of a network simulation using the ns-3 simulator. It demonstrates the use of 802.11 QoS (Quality of Service) for different Access Categories (ACs) in a Wi-Fi network. The simulation consists of four independent Wi-Fi networks, each

with an access point (AP) and a station (STA). Each STA continuously transmits data packets to its respective AP.

### **A . The network project is as follows:**

The code starts by including the necessary header files and defining the required name spaces.

- It sets up the logging component for the simulation.
- The main function begins by parsing command-line arguments to set various parameters such as payload size, simulation time, distance between nodes, and more.
- Node Container is used to create four STA nodes and four AP nodes.
- YansWifiChannelHelper and YansWifiPhyHelper are used to set up the physical layer of the Wi-Fi network.
- WifiHelper is used to configure the Wi-Fi standard and the remote station manager.
- WifiMacHelper is used to set up the MAC layer of the Wi-Fi network for STAs and APs.
- NetDeviceContainer is used to hold the STA and AP devices.
- Different SSIDs are assigned to each network.
- The EDCA (Enhanced Distributed Channel Access) parameters are modified for specific ACs (AC\_BE, AC\_VI and AC\_VO) to change the TXOP (Transmit Opportunity) limits.
- The mobility of the nodes is set using the MobilityHelper and ConstantPositionMobilityModel.
- The Internet stack is installed on the nodes using the InternetStackHelper.
- IP addresses are assigned to the devices using the Ipv4AddressHelper.
- Server and client applications are set up using the UdpServerHelper and OnOffHelper classes.
- The simulation is run for the specified duration.

## **B. The simulation parameters**

This example provides how to configure and simulate a Wi-Fi network with different QoS requirements for different traffic classes. It demonstrates the use of ns-3's capabilities to model and evaluate network protocols and scenarios.

### 1. Access Category Best Effort (AC\_BE):

- No specific configuration for AC\_BE is mentioned in the code.

### 2. Access Category Background (AC\_BK):

- STA B sends AC\_BE traffic to AP B with a default AC\_BE TXOP value of 0 (1 MSDU).
- Default TXOP limit for AC\_BE is not modified, so it uses the default value.

### 3. Access Category Video (AC\_VI):

- STA C sends AC\_VI traffic to AP C with a default AC\_VI TXOP of 3.008 ms.
- TXOP limit for AC\_VI is modified for AP C to 3.008 ms

### 4. Access Category Voice (AC\_VO):

- STA D sends AC\_VO traffic to AP D with a AC\_VO TXOP value of 1.504 ms

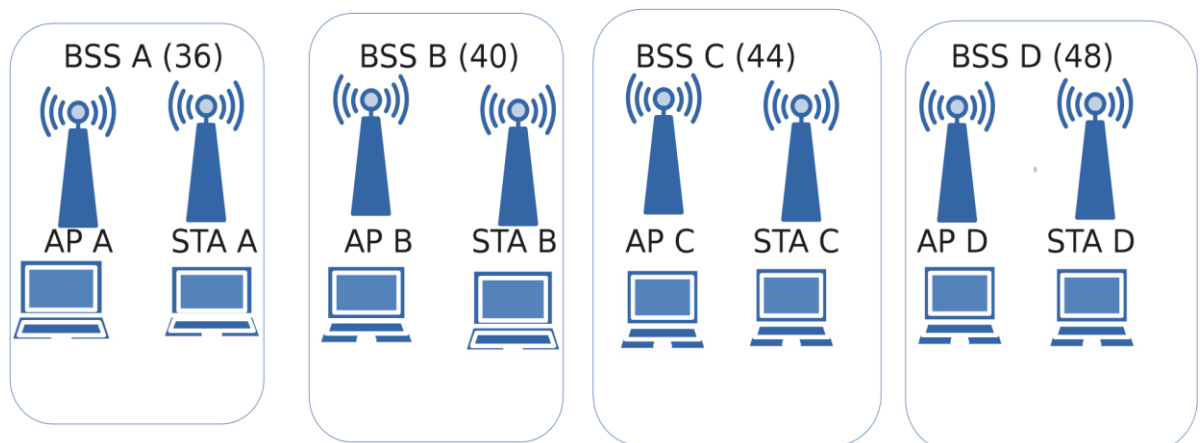


figure 2.15 network topology

Table 2.5: Parametrizes EDCA

Traffic Class	AC_BE (Best Effort)	AC_VI (Video)	AC_VO (Voice)
AIFSN	3	2	2
CWmin	15	7	3
CWmax	1023	15	7
Sending rate	256k	1024 kb/s	512 kb/s
TXOP Limit	Default	3.008 ms	1.504 ms

Please note that the AIFSN, CWmin, and CWmax values are commonly used parameters for each Access Category, while the TXOP limit may vary depending on the specific requirements and configurations of the network. The values provided here are based on the code snippet you provided,

## **2.5 Simulation results and analysis for the scenario:**

The code allows customization of various parameters such as payload size, simulation time, and distance between stations and APs through command-line arguments. The throughput measured for each case/network is printed as the output.

```
lenovo@lenovo-ThinkPad-L440: ~/Bureau/ns-allinone-3.36.1/netanim-3.108$ cd ..
lenovo@lenovo-ThinkPad-L440: ~/Bureau/ns-allinone-3.36.1$ cd ns-3.36.1
lenovo@lenovo-ThinkPad-L440: ~/Bureau/ns-allinone-3.36.1/ns-3.36.1$ ./ns3 run "scratch/wifi-80211e-txop1 --distance=10 --simulationTime=10 --payloadSize=1000"
Consolidate compiler generated dependencies of target scratch_wifi-80211e-txop1
```

figure 2.16 : showing Command line

like we said the Variables the we can change is the distance the time of the simulation and the payload size

```

lenovo@lenovo-ThinkPad-L440:~/Bureau/ns-allinnone-3.36.1$ cd ns-3.36.1
lenovo@lenovo-ThinkPad-L440:~/Bureau/ns-allinnone-3.36.1/ns-3.36.1$ ./ns3 run "scratch/wifi-80211e-txop1 --distance=10
-simulationTime=10 --payloadSize=1000"
Consolidate compiler generated dependencies of target scratch_wifi-80211e-txop1
[ 0%] Building CXX object scratch/CMakeFiles/scratch_wifi-80211e-txop1.dir/wifi-80211e-txop1.cc.o
[ 0%] Linking CXX executable ../../build/scratch/ns3.36.1-wifi-80211e-txop1-default
PING 192.168.1.1 - 56 bytes of data - 84 bytes including ICMP and IPv4 headers.
64 bytes from 192.168.1.1: icmp_seq=0 ttl=64 time=+345.282ms
64 bytes from 192.168.1.1: icmp_seq=1 ttl=64 time=+168.378ms
64 bytes from 192.168.1.1: icmp_seq=2 ttl=64 time=+168.206ms
--- 192.168.1.1 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time +3000ms
rtt min/avg/max/mdev = 168/227/345/102.2 ms
Max Packets per trace file exceeded
AC_BE with default TXOP limit (0ms):
  Throughput = 23.8496 Mbit/s
AC_BE with non-default TXOP limit :
  Throughput = 0.2552 Mbit/s
  Maximum TXOP duration = 224 us
AC_VI with default TXOP limit (3.008ms):
  Throughput = 1.0232 Mbit/s
  Maximum TXOP duration = 292 us
AC_VO with default TXOP limit (1.504):
  Throughput = 0.5112 Mbit/s

```

figure 2.17 the result of throughput

like we see in the figure above the output is the throughput and the maximum TOXP duration ,in this case we see that the big duration is AC\_VI(vidio) . After that came the AC\_VO and AC\_BE with lower throughput . But in the first AC\_BE a lote of throughput and the because the Data Rate is not like the second one is so hair and that give us bigger throughput but that give a lot of data lost and we will see in the next result when we use netanim

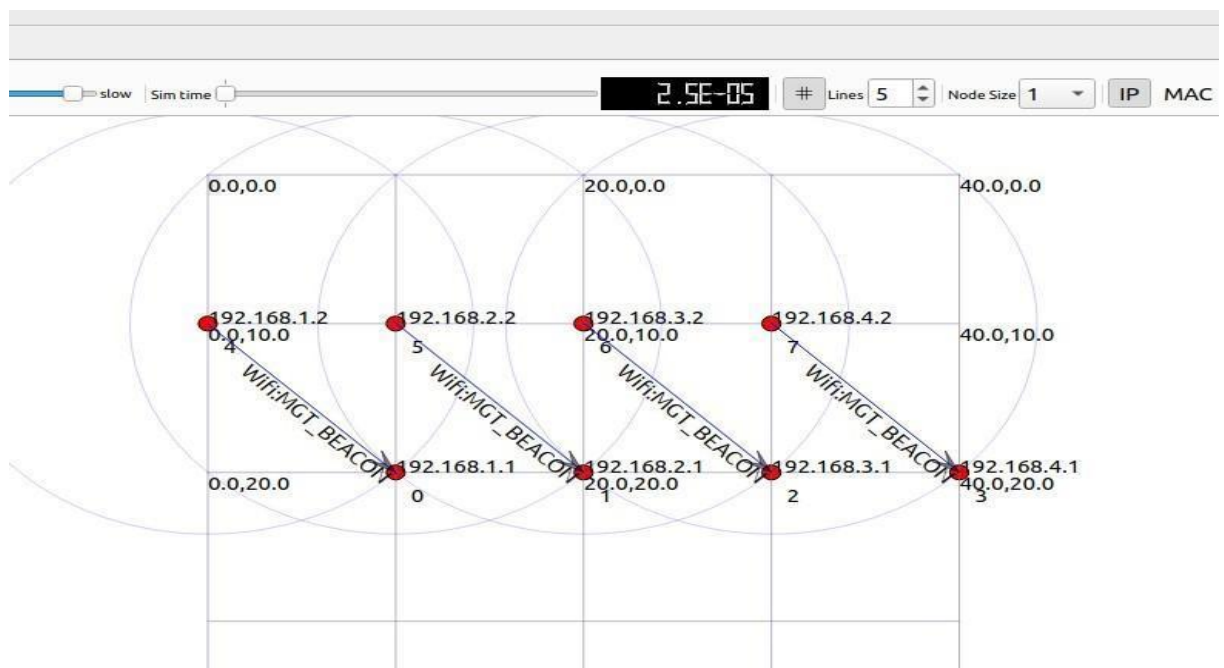


figure 2..18 : topology in netanim

we see in this figure below the amount of data lost ratio and the mean delay wish we need to study for each network

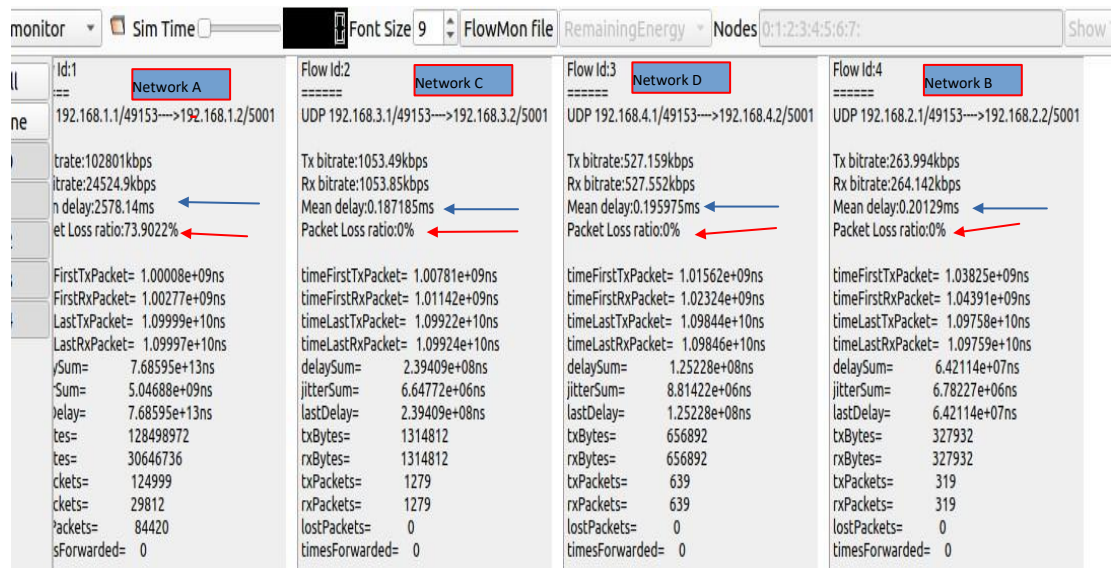


figure 2.19 Nam result (delay and data lost)

we see in this figure that showing the amount of data lost ratio and the mean delay wish we need to study for each network

## A. data and result

### a. case1 :(distance =10 and simulation time=1 and **payload =X** )

in case one we vary the simulation time and the distance the same but we change the payload size

#### 1.DELAY :

Table 2.6 case 1 delay of AC\_(BK ....VI....VO)

<u>payload/delay</u>	AC_B K	AC_VI	AC_vo
100	78.1	59.3	81
200	99	74	106
500	199	126	170
1000	360	211	301



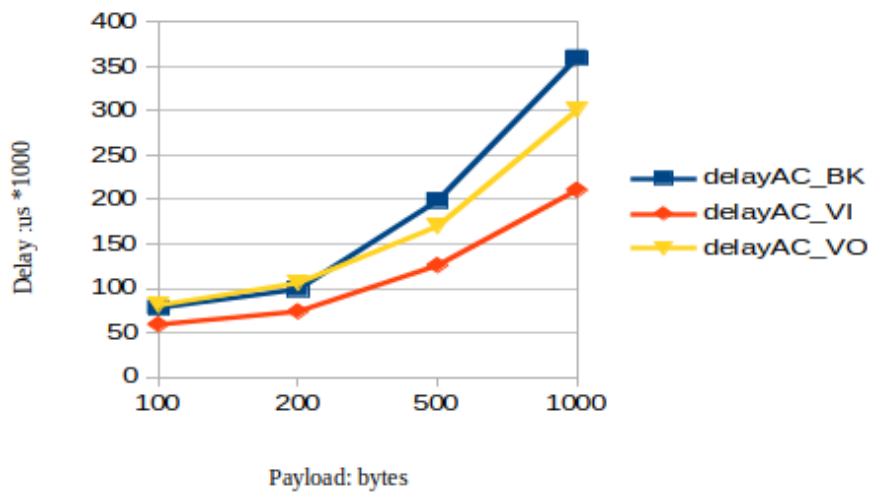


figure 2.20 case 1 delay of AC\_(BK ....VI....VO)

In this graph the delayAC\_Bk is high then the other delays even when we change the payload size

## 2.throughput

Table 2.7 throughput of AC\_(BK ....VI....VO)

<u>payloa</u> <u>d</u>	AC_B K	AC_VI	AC_vo
100	253.6	1021	509
200	252.8	1022	510
500	252	1020	508
1000	248	1016	504

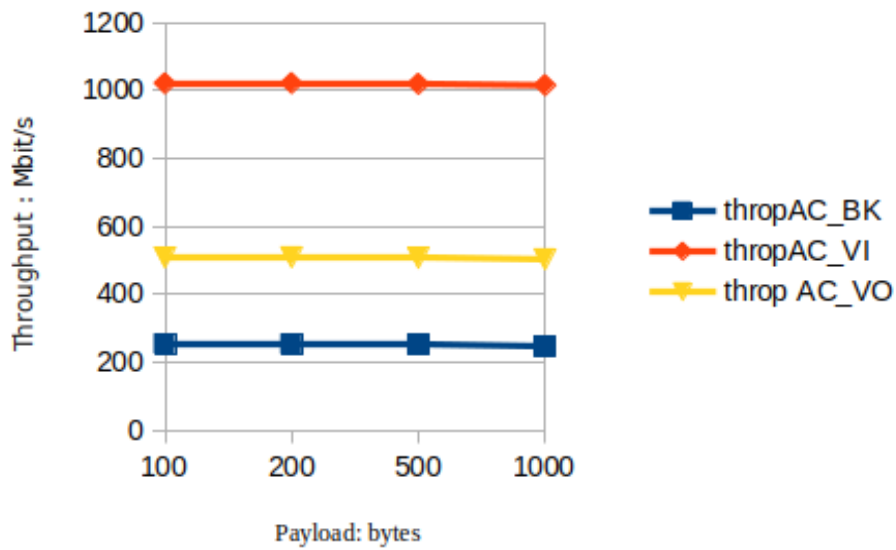


figure 2.21 throughput of AC\_(BK ....VI....VO)

In the throughput the AC\_vidio has the highest one

**b. case 2 :(distance =X and simulation time=1 and payload =1000 )**

Case number two we change the distance and we let the other two the same

**1.Throughput :**

Table 2.8 case 2 throughput of AC\_(BK ....VI....VO)

<u>distanc</u> <u>e</u>	AC_B K	AC_VI	AC_vo
10	248	1016	504
20	248	1016	504
50	248	1016	504
60	248	1016	504

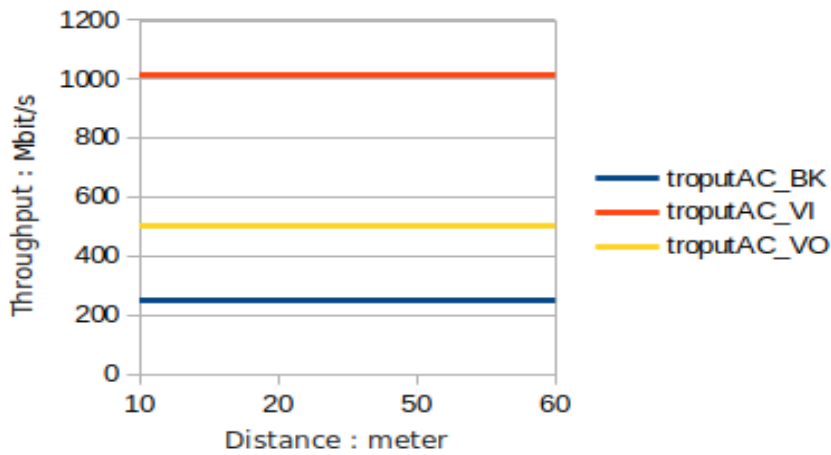


figure 2.22 case 2 throughput of AC\_(BK ....VI....VO)

## 2. DELAY ;

Table 2.9 case 2 delay of AC\_(BK ....VI....VO)

<u>distance</u>	AC_BK	AC_VI	AC_vo
10	360	211	301
20	400	260	370
30	450	320	420
50	561	411	502

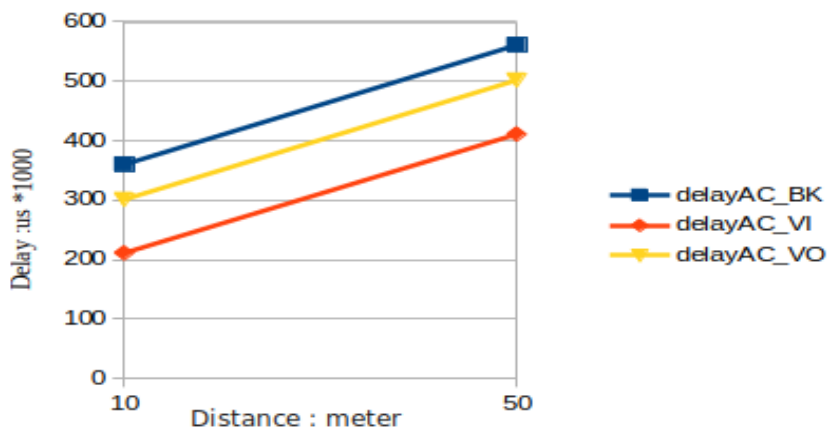


figure 2.23 case 2 delay of AC\_(BK ....VI....VO)

### **c. case 3 : (distance =10 and simulation time=X and payloadsize =1000)**

In this case we've changed the simulation time and we let the payload size and the distance the same

### 1.Throughput ;

Table 2.10 case 3 throughput of AC\_(BK ....VI....VO)

<u>simulation time</u>	AC_BK	AC_VI	AC_vo
1	248	1016	504
10	255	1020	511
15	255.1	1022	511.2
20	255.1	1023	511.2

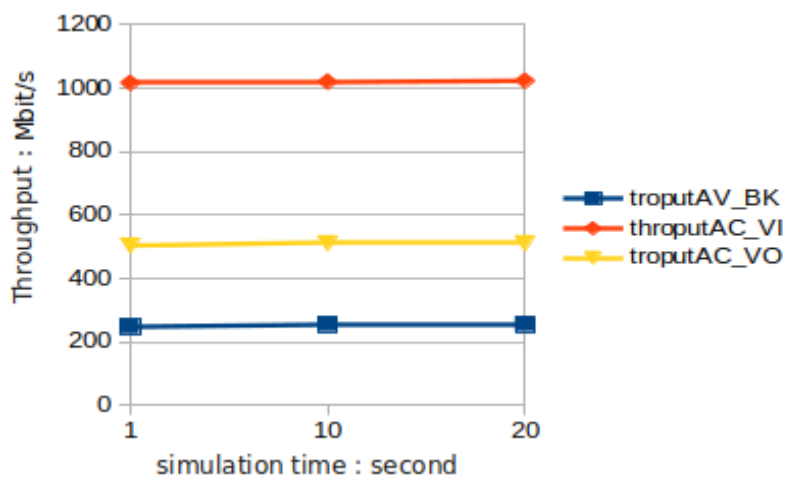


figure 2.24 case 3 throughput of AC\_(BK ....VI....VO)

### 2. DELAY ;

Table 2.11 case 3 delay of AC\_(BK ....VI....VO)

	AC_BK	AC_VI	AC_vo
1	360	211	301
10	401	386	307
15	350	400	350
20	397	400	300

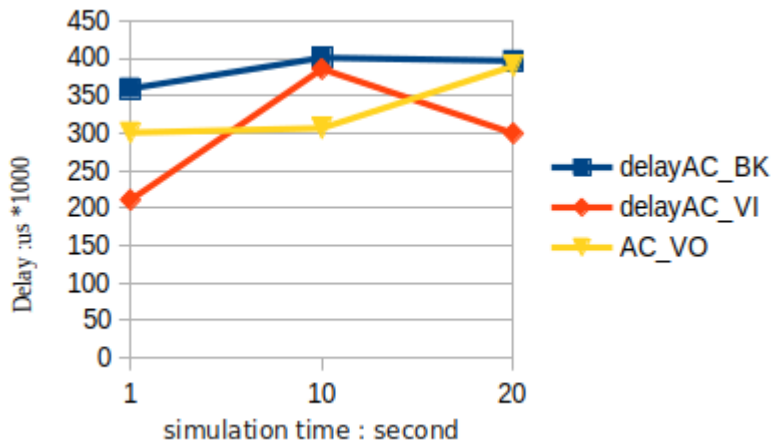


figure 2.25 case 3 delay of AC\_(BK ....VI....VO)

## **B. Understand the results**

The IEEE 802.11e protocol prioritizes the throughput of video in order to ensure high-quality video streaming. This is because video applications require a continuous and uninterrupted stream of data to deliver smooth playback without buffering or delays. By prioritizing the throughput of video packets, the protocol aims to provide a better user experience and maintain the desired quality of video content. This prioritization helps to minimize packet loss, reduce latency, and ensure that video data is transmitted efficiently and effectively within the wireless network.

While the IEEE 802.11e protocol primarily focuses on prioritizing throughput for video, it also takes into consideration the importance of minimizing delay. Delay is a crucial factor in real-time applications, including video streaming, as excessive delays can result in noticeable lags or disruptions in the playback.

The delay of background traffic is typically prioritized as the highest. Background traffic refers to low-priority data transmissions that are not time-sensitive, such as file downloads or software updates. These types of traffic are considered less critical and can tolerate higher delays without significantly impacting user experience or quality of service; By assigning higher priority to other types of traffic, such as video or voice, the protocol aims to reduce the delay

for time-sensitive applications while allowing background traffic to experience higher delays. This prioritization ensures that time-sensitive applications receive sufficient bandwidth and lower latency, while non-time-sensitive applications are allocated resources accordingly, giving preference to the more critical traffic.

## **2.6 Comparisons between Qos protocol and non**

### **Qos protocol:**

In this comparison we will have to scenario one in to point connecting with QoS and the in the scenario without the QoS and that give us a good view on the data that we have wish is the delay and the throughput during the time of simulations . [25] look at the scenario 2 (with Qos ) and the scenario 3 (without QoS)

### **2.6.1 End-to-End Delay:**

#### **A.NON QoS :**

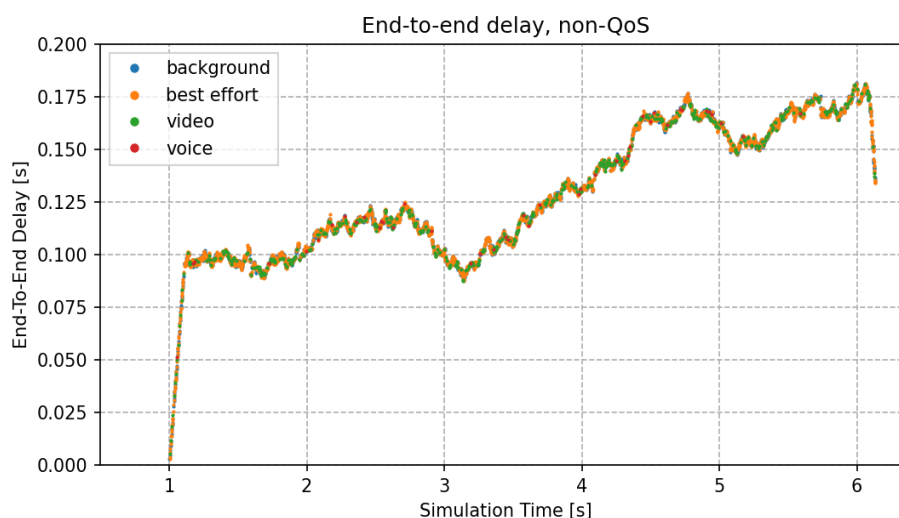


Figure 2.26 end to end delay without QoS [25]

The end-to-end delay vector data points for the four access categories run together because the MAC treats all packets the same [25]

The curve is straight and steep at the beginning, due to the queue being filled up. When it is already filled up, the delay starts to fluctuate. The UDP applications generate more traffic than the channel can carry, thus the queue

stays filled up, and packets are dropped. Note that dropped packets are not indicated on the charts, as we're plotting UDP packets received by the server.

## B.QoS :

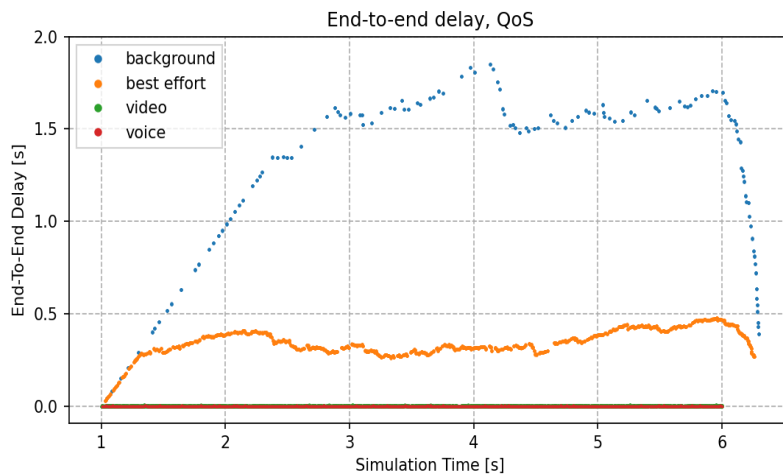


Figure 2.27 end to end delay with QoS [25]

In the QoS case, as expected, the higher priority access categories (video, voice) have lower delay, because they are often sent before the lower priority ones (they are more likely to be sent first.)

## 2.6.2 Throughput:

### A.NON QoS :

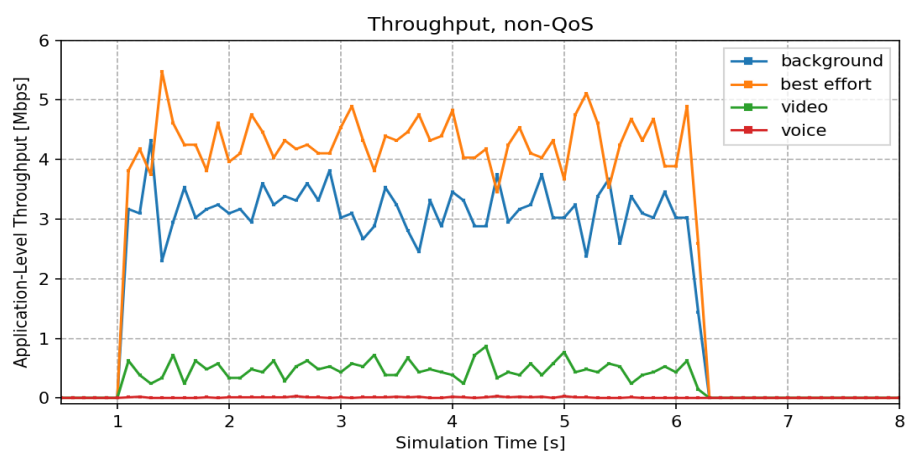


Figure 2.28 throughputs without QoS [25]

The throughput for the four applications is more or less proportional to their generated traffic (more for background and best effort, less for video and even

less for voice). However, none of the access categories can send data at the rate the the

Application is generating it because all four categories have the same chance for gaining access to the channel, and the channel is saturated. [25]

### **B.Qos :**

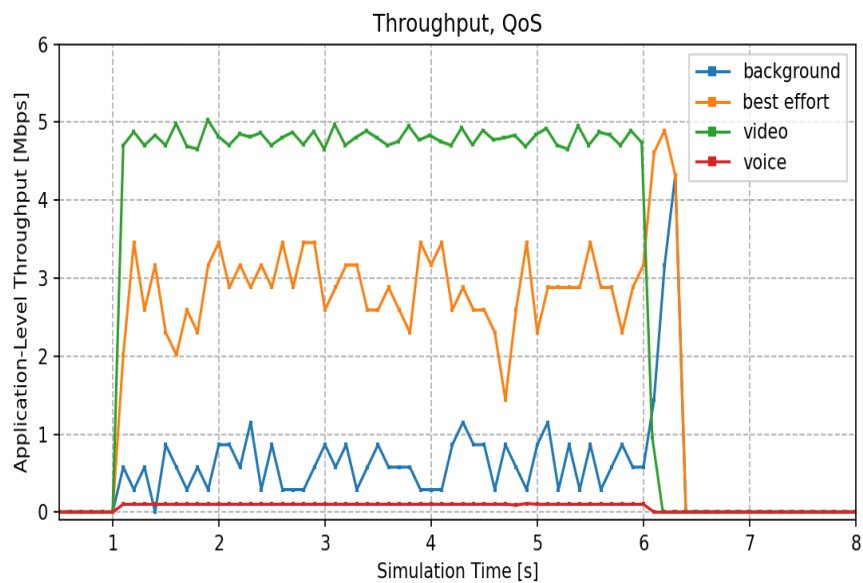


Figure 2.29 throughput without QoS [25]

Throughput for the video and voice categories can reach their nominal bitrate. The throughput for the background and best effort categories is lower while the high priority ones have data to send, and increases just a bit when the

High priority traffic stops (there are still some packets left in the background and best effort queues).

## **2.7 Conclusion**

The results reveal that the priority remains the same, and the values that we constantly change affect the quantity of throughput and the delay, but not the priority itself. The EDCA parameters can fulfill specific Quality of Service (QoS) requirements. The CWmin parameter determines the size of the interval from



which the interrupt counter is triggered. A smaller CWmin results in a smaller back off counter, allowing a station to reach 0 faster because stations always have packets to transmit. Stations with a smaller CWmin can transmit a higher number of packets.

EDCA controls and manages the transfer of data, making it more efficient. This prioritizes packet delivery, reducing delay and data loss. Furthermore, factors such as distance and payload play a significant role. However, with EDCA, the principle of "first come, first served" is maintained.

We assessed the performance of the EDCA mechanism for quality of service support in the IEEE 802.11e WLAN. Through our simulations, we compared the old 802.11 DCF and the 802.11e EDCA to show that the EDCA provides differentiated channel access for different types of traffic and is better equipped than DCF to manage real-time applications with stringent quality of service requirements. We find that with heavy traffic connections under significant background traffic, the EDCA mechanism is not able to provide a guarantee of quality of service. Better results can be achieved if we can adapt the EDCA settings during execution according to the load of the network and the supported applications.

# CONCLUSION AND FUTURE WORK

With the growing and fast popularity of WLANs, the demand for Existing WLAN standards is more important than ever. Therefore, the Work IEEE 802.11 took responsibility for improving the MAC 802.11 [3] to include Quality of Service (QoS) to support multimedia applications such as VoIP and video conferencing. As a result, IEEE 802.11e [3] was published to provide QoS capabilities in emerging WLANs by introducing an Enhanced Distributed Channel Access (EDCA) technique based on a restraint.

The EDCA function (abbreviated to EDCAF) introduced by the IEEE is based on the Access Categories (ACs) concept. It can support quality of service by introducing differentiation of service [11, 22].

In this research, we first studied the impact of EDCA QoS parameters, such as CWmin, AIFS respectively, by means of a flow rate analysis on the performance of the EDCA function. Then we presented a study of simulating QoS support in wireless local area networks using EDCF 802.11e and compared its performance with 802.11. The simulation has been performed on the NS3 platform where we used the existing 802.11 DCF codes and implemented core EDCF functionality in NS3.

For future work, we hope to improve the proposed schemes and test them with different scenarios using different traffic (uniform, burst,).

We will also try to study the EDCA method and the effect of each parameter to find a relationship between the different parameters to adjust them dynamically in addition to taking into account the link status, but more research is needed to obtain better quality of service (QoS).

# Reference

- [1] Anand R. Prasad, Neeli R. Prasad: "802.11 WLANs and IP Networking Security, QoS, and Mobility", ARTECH HOUSE, 2005, ISBN: 1-58053-789-8.
- [2] IEEE 802.11, IEEE Standards for Information Technology Specific Requirements -Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications. Edition (ISO/IEC 8802-11: 1999).
- [3] IEEE, "Standard 802.11," in PART 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, ed, 2007.
- [4] IEEE, "Standard 802.3 " in Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications, ed, 1985.
- [5] IEEE 802.11 WG, Reference number ISO/IEC 880211:1999(E) Std 802.11,1999 edition International Standard {for} Information Technology – Telecommunications and information exchange between systems- Local and metropolitan area network-Specific Requirements – Part 11:Wireless LANMedium Access Control (MAC) and Physical Layer (PHY) specifications, 1999.
- [6] Nabil OUAZENE, « Pour une QoS au niveau de la Couche MAC dans les Réseaux Sans Fil » , Mémoire de Magister, Université Hadj Lakhdar BATNA, 2009.
- [7] Belabdelli Abdelheq,Oukaz Mokhtar . « Dimensionnement d'un Réseau Sans Fil Wifi », Mémoire de fin d'études. Université abou bekr belkaid .2012.
- [8] Dufresne Loïc. «Quel est l'effet de la QoS sur des petits réseaux de labo ?», Thèse doctorat. Haute école d'ingénierie et d'architecture fribourg.2018.

- [9] Mohamed Lamine Lamali . «Qualité de service et calcul de chemins dans les réseaux inter-domaine et multicouches», Thèse doctorat. Université de Versailles Saint-Quentin.2015.
- [10] Q. Ni, et al., "A Survey of QoS Enhancements for IEEE 802.11 Wireless LAN," Journal of Wireless Communications and Mobile Computing, vol. 4, 2004.
- [11] A. Helal, et al., "Any Time Anywhere Computing: Mobile Computing Concepts and Technology," Kluwer Academic Publishers, October 1999.
- [12] J. Kurose and K.Ross, Eds., Computer networking: a top-down approach featuring the Internet. Addison-Wesley, 2003, p.^pp. Pages.
- [13] B. Crow, et al. (September 1997) IEEE 802.11 Wireless Local Area Networks.IEEE Communications Magazine.
- [14] Veeraraghavan and N. Cocker, "Support of voice services in ieee 802.11 Wireless LAN," Proceedings Infocom 2001, 2001.
- [15] M. Visser and M. ElZarki, "Voice and data transmission over an 802.11 wireless network," Proceedings of IEEE Personal, Indoor & Mobile Radio 1995.
- [16] I. Aad and C. Castelluccia, "Differentiation mechanisms for IEEE 802.11," Proceedings of IEEE Infocom 2001, Anchorage, Alaska, USA, 2001.
- [17] D. He and C. Shen, "Simulation Study of IEEE 802.11e EDCF," IEEE Vehicular Technology Conference, 2003.
- [18] F. Roijers, et al., "A performance study on service integration in IEEE 802.11E wireless LANs," Computer Communications 29 2006.
- [19] <https://standards.ieee.org/products-programs/ieee-get-program/>
- [20] Benveniste, "Tiered Contention Multiple Access' (TCMA), a QoS-Based Distributed MAC protocol", Proceedings PIMRC 2002, Lisboa, Portugal, September 2002

- [21] M. Benveniste, "WLAN QoS", Chapter 3 in Emerging Technologies in Wireless LANs Theory, Design, and Deployment, (B. Bing, ed.), Cambridge University Press, 2008,
- [22] X.Pérez-Costa, D.Camps-Mur and T.Sashihara. Analysis of the Integration of IEEE 802.11e Capabilities in Battery Limited Mobile Devices. IEEE Wireless Communications Magazine (WirComMag), special issue on Internetworking Wireless LAN and Cellular Networks, Volume 12, Issue 6, December 2005.
- [23] M. Benveniste, "Guidelines for Power Management", Doc IEEE 802.11-04/073, January 2004
- [24] <https://www.nsnam.org/about/what-is-ns-3/>
- [25] <https://inet.omnetpp.org/docs/showcases/wireless/qos/doc/index.html#id1>
- [26] Advanced Network Simulations Simplified particle guide for wired WIFI (802.11n/ac/ax),and LTE networks using ns3 writing by dr ANIL KUMAR RANGISETTI
- [27] M : LAOUAR Samir Mémoire de Fin d'Étude pour l'Obtention du Diplôme de Master en Informatique Evaluation des performances des protocoles IEEE 802.11e Année 2019-2020