ENSC 894 - COMMUNICATION NETWORKS

Analysis of Enhanced Distributed Channel Access in Wireless Local Area Network using OPNET

Spring 2014

Project Report

Team #2

Syed, Aitizaz Uddin (Student-ID: 301190558)<asyed@sfu.ca>

Shen, Shiou-Min (Student-ID: 301004884)<eshen@sfu.ca>

1 Abstract

Wireless local area networking (WLAN) has experienced tremendous growth over the last decade with the proliferation of IEEE 802.11 devices. Every day thousands of devices are made which are compatible with the 802.11. Such interoperability of different vendor's devices is ensured by Wi-FI Alliance (WFA). Over the years WLAN has achieved good improvement in throughput at PHY layer due to introduction of 802.11b, 802.11g, 802.11n and 802.11a standards. At the Data link layer the technology has been the same protocol Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) which allows half duplex communication between nodes sharing the license-free channels equally. CSMA/CA lacks in capability when we want end-to-end QoS architecture of the existing wired network. In order to incorporate existing wired LANs QoS infrastructure in wireless LANs, "Enhanced Distributed Channel Access (EDCA)" is introduced in amendment 802.11e which ensures the desired order of preference for channel access to the applications as it is in wired LANs.

In this project we create a simulation model in OPNET of the enterprise access network. The connectivity of the end nodes are dependent on wireless media. We observe the influence of quality of service (QoS) of wired LAN and then WLANs by enabling EDCA. We observe response of different applications in CSMA/CA based equal opportunity channel access mode and in EDCA enabled mode of preference based channel access.

Table of Contents

List of Figures

List of Tables

2 Introduction

Wireless Local Area Network (WLAN) has been in development since the deployment of the first wireless network, ALOHANet, in 1970s. WLAN setup used to be expensive and vendor specific, but the 802.11 standard introduced by Institute of Electrical and Electronics Engineers (IEEE) in 1997 unified the standards and became the mainstream WLAN implementation in the industry.[9] With the advancement of technology, 802.11 also went through many amendments; currently the most widely used WLAN devices implements 802.11g and 802.11n.

With cost reduction, ease of use, and mobility, WLAN is emerging as a viable alternative for wired LAN. However, it differentiates from wired LAN in many ways. Wireless stations establish connection using half-duplex communication instead of full duplex, and they compete for a shared media in license free band. Half duplex links cannot send and receive at the same time, so the wireless stations cannot detect collisions when they are busy sending data. Having only a limited range of frequency to communicate and having to share channels with many other devices, the design of a wireless network is drastically different from the design of a wired network.

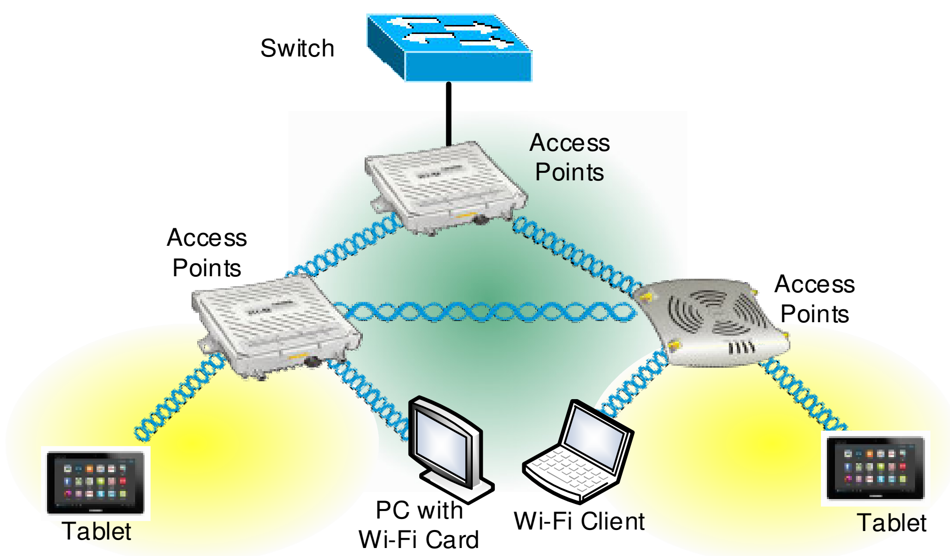


Figure 1 Wireless Local Area Network

EEE 802.11 employs Distributed Coordination Function (DCF) for channel access control. DCF provides equal access for every wireless station and doesn't distinguish between different types of applications. With increase in usage of video and audio applications, DCF is unable to provide smooth service to these applications because of its indifference to the application types. Unlike WLAN, wired networks already dealt this issue with Type of Service (ToS) which categorizes applications and provide appropriate priority for different traffics. To bring this Quality of Service (QoS) mechanism to WLAN, IEEE introduces 802.11e amendment in which Hybrid Coordination Function (HCF) is used in place of DCF. HCF provides priority to data according to its type so QoS is guaranteed for video and audio applications.

To observe the effect of QoS mechanisms on video and audio traffic in wireless network, an experiment with a reasonably realistic simulation setup is required to verify it. A comparison between multiple types of traffic with no QoS and with QoS in a populated WLAN should display improvement in video and audio traffic with QoS activated. This will become evident in the analysis when we examine the delay, jitter, and throughput of the simulation.

3 Background Knowledge

3.1 Wireless Data Communication Technologies

Whenever it comes to wireless data communications we see different technologies around us such as satellite, cellular, long-range microwave, infrared etc. Although these technologies use the same atmospheric air as media of communication, but their characteristics vary in terms communication range, cost, data rates, services, and operating frequencies. These technologies serve different purposes to the human being. Based on their coverage area they are classified into 4 categories.

3.1.1 Personal Area Network (PAN)

In PAN we are interested in coverage up to few meters or coverage to things within users reach. Since data communication devices are in reach, there is half-duplex communication for small amount of time. Hence simple 3-way handshake before communication is sufficient to establish a secure link. The amount of power required is very low because data is transferred easily within respective range and no issuance of license is required. Power level is assured not to exceed the level threshold provided by governing authority. Also, the communication coverage area is so small that no allocation of frequency band per user is needed, and the same band can be reused within a house and building. Data rates may vary from 1Mbps to 300 Mbps+. Examples of such technologies are Bluetooth, Infrared, Near Field Communication (NFC) etc.

3.1.2 Local Area Network (LAN)

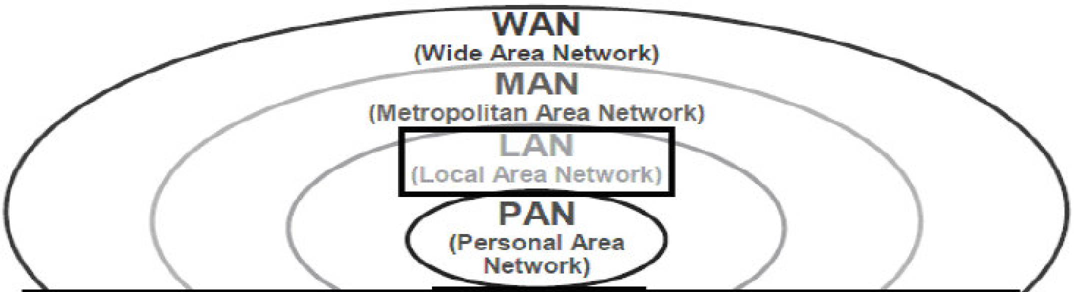
In LAN we consider range of the size of a house or building. In other words LAN is group of users in the same vicinity having a common gateway to connect to outside world. In LAN, with more devices in the network, high level of security is required. The required power to communicate is considerably low and is restricted by governing authority because this communication is on license free band. The frequency usage may vary within the building by selecting non-overlapping channels. Data rate vary from 1Mbps to 3Gbps+ nowadays. Example of such technology is WLAN whose amendments over the years are 802.11b, 802.11a, 802.11g, 802.11ac and 802.11n.

3.1.3 Metropolitan Area Network (MAN)

In MAN, the area of coverage is now of a city. Users are distributed throughout city to which connectivity services are provided and very high level security is necessary to ensure only these users can connect. Required power of transmission is high, and licensed frequency bands are purchased from the authorities. Data rates may exceed to 50 Mbps in multipoint communication such as WIMAX (Worldwide Interoperability for Microwave Access) and in point-to-point up to 500Mbps on Long range Microwave bridges.

3.1.4 Wide Area Network (WAN)

WAN communication includes coverage area of multiple cities, countries and may be the entire world. Hence the technology should be capable of communicating to the required users geographically distributed throughout world. Satellite technology is an example of WAN. Security in form of data encryption and data hiding is required in multiple technologies; for example TV broadcast etc. Data transmission is less than 500 kbps.



	PAN	LAN	MAN	WAN
Standards	Bluetooth	IEEE 802.11a, 802.11b, 802.11g	802.16 MMDS, LMDS	GSM, GPRS, CDMA, 2.5–3G
Speed	<1 Mbps	1–54+ Mbps	22+ Mbps	10–384 kbps
Range	Short	Medium	Medium–long	Long
Applications	Peer to peer, device to device	Enterprise networks	Fixed, last-mile access	PDAs, mobile phones, cellular access

Table 1 Wireless LANs characteristics among wireless data communication technologies [8]

3.2 Physical Layer of Wireless LANs

The WLAN communication started in 1980s using Direct Spread Sequence Spectrum (DSSS) on 900 MHz on license free channel. As time progressed, more and more users started to adopt this technology, computers became faster and more common. More versatile spectrum of 2.4 GHz was selected to improve throughput and reduce interference. Also WI-Fi Alliance was established in 1999 to ensure interoperability of technology by certifying Wi-Fi products and conforming them to the non-proprietary open standards.

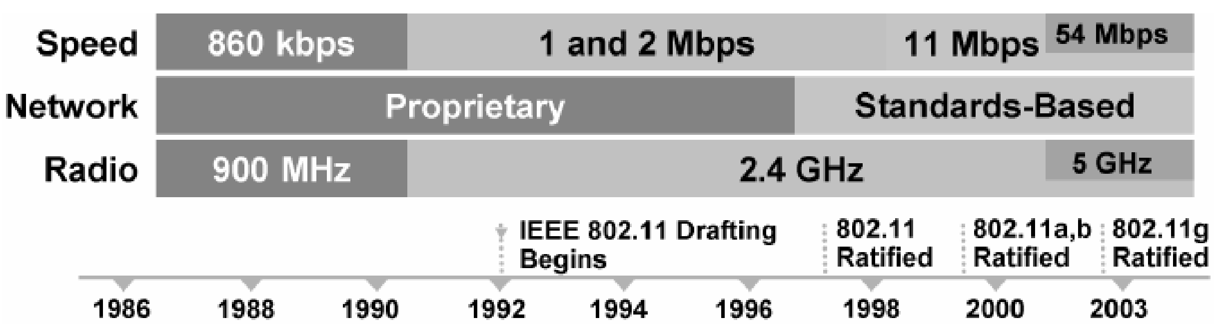


Table 2 WLAN frequency Ranges [8]

3.2.1 Frequency Bands

For WLAN there are 2 frequency bands specified. The 2.4-GHz band provides 83 MHz of total contiguous bandwidth, spanning from 2.4 to 2.483 GHz. In this band fourteen 22 MHz channels are formed in which two consecutive channels are 5 MHz apart. [1]

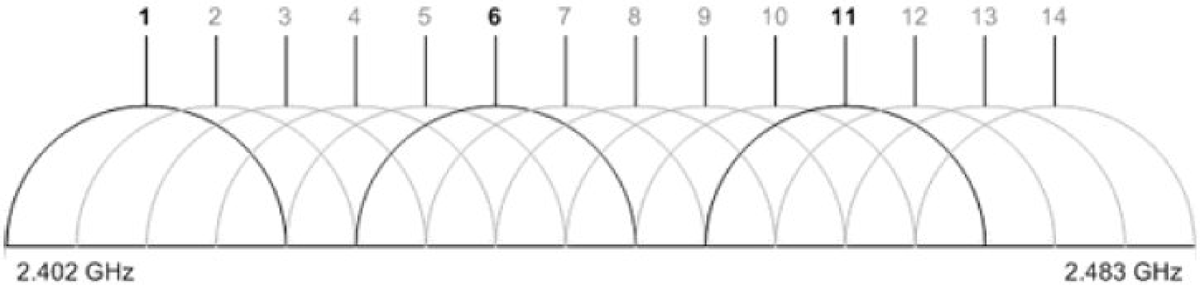


Figure 2 Channels in 2.4 GHz WLAN spectrum. [8]

The second band is 5 GHz. In 5 GHz we get two ranges of spectrum. One ranging from 5.15 to 5.35 is referred as the lower spectrum while 5.75 to 5.825 is the higher spectrum. Now in lower spectrum 8 channels are spaced across 200 MHz while in higher spectrum 4 channels are spaced across 100 MHz.

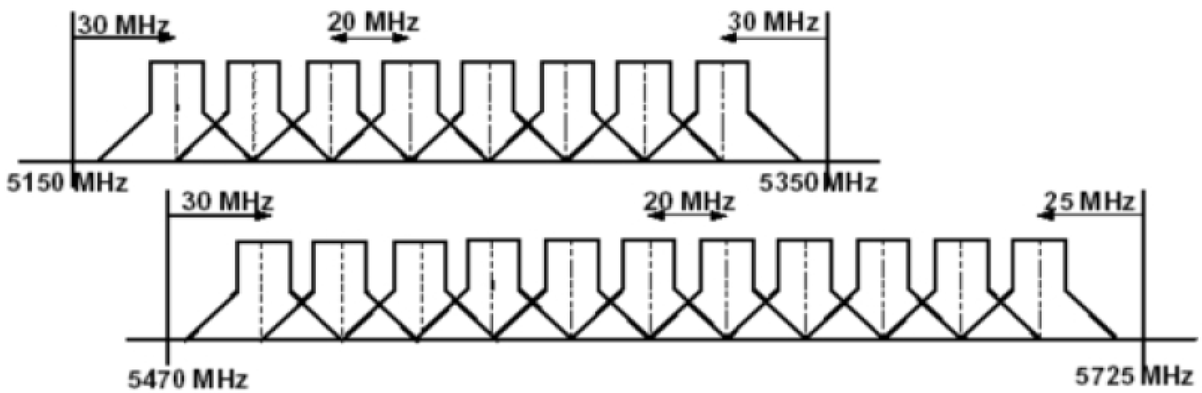


Figure 3 Channels in lower and higher spectrum of 5 GHz [8]

3.2.2 IEEE 802.11 Family

The 802.11 family includes multiple PHY and Data link layer communication technologies proposed over the years as a standard to improve range, throughput and performance of communication devices. All these 802.11 standards are updated time to time in form of standardized drafts to which devices should comply to ensure interoperability of vendor products. Following are the PHY layer standards proposed over the years.

3.2.2.1 IEEE 802.11 (legacy)

Released in 1997, it provides data rates of 1Mbps and 2Mbps using Frequency Hopping Spread Spectrum (FHSS) or Direct Spread Sequence Spectrum (DSSS) at frequency band of 24 GHz.

3.2.2.2 IEEE 802.11a

Released in 1999, 802.11a used OFDM (Orthogonal Frequency Division Multiplexing) which performed modulation and multiplexing of multiple data bits simultaneously over multiple orthogonally arranged sub-carriers achieving throughput of up to 54 Mbps at frequency of 5 GHz. Since the 2.4GHz band was already adopted, 802.11a didn't achieve required fame and slowly disappeared from the market.

3.2.2.3 IEEE 802.11b

Released in 1999, operating at 2.4 GHz, 802.11b was backward compatible with the legacy 802.11 providing 1 and 2 Mbps using DSSS modulation. 802.11b also provided higher data rates of 5.5 Mbps and 11 Mbps by employing a modulation scheme called complementary code keying (CCK).

3.2.2.4 IEEE 802.11g

Released in 2003, operating at 2.4 GHz, 802.11g extended data rates up to 54 Mbps using OFDM (Orthogonal Frequency Division Multiplexing). 802.11g devices were embedded with the DSSS modulation circuitry so that backward compatibility is maintained.

3.2.2.5 IEEE 802.11n

By 2007 due to demands of the high throughput, wired LAN technologies were upgraded to achieve 1Gbps and 10Gbps. Thus it was necessary to upgrade WLANs to compete with wired-LAN. New techniques were introduced in 802.11n such as MIMO (Multiple Input Multiple Output) and channel aggregation of 20 MHz to increase throughput and creating a burst of transmission between nodes called "High Throughput" mode. In 2010, 802.11n was standardized which achieved maximum throughput of 600 Mbps.

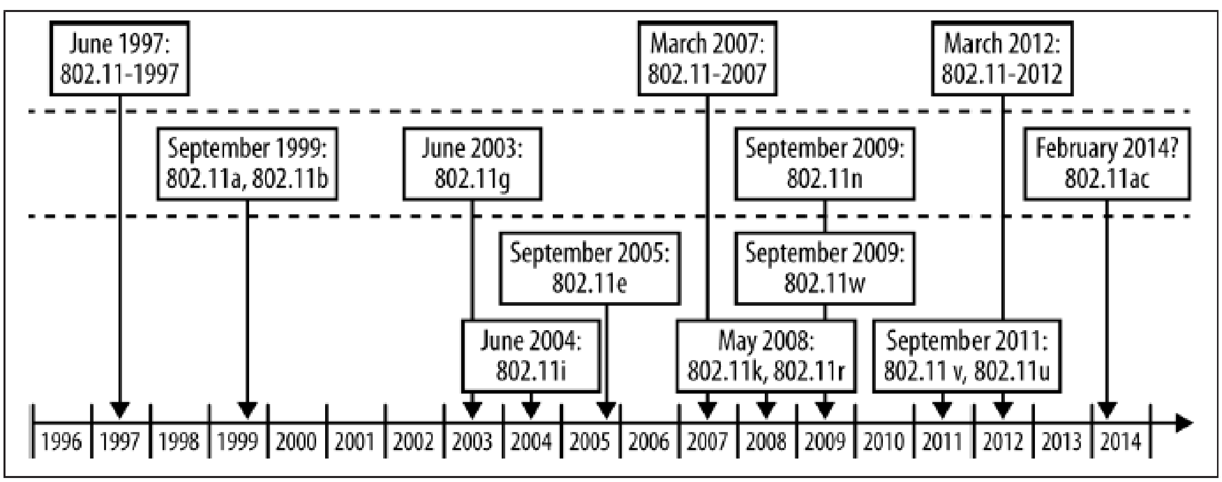


Table 3 WLAN Physical layer standards over the years [10]

3.3 Data Link layer in Wireless LANs

At data link layer we have 2 sub-layers MAC and LLC. The MAC sub- layer of data link layer interacts with the physical layer for transmission of data over the channel and is responsible for channel access for the data over wireless media. For such action following are coordination functions in WLANs.

3.3.1 Point Coordination Function (PCF)

PCF is the synchronous data transmission method in which the central node access point (AP) act as a controlling agent and coordinates which node is allowed to communicate over channel at an instant. PCF based wireless communication cannot predict hidden node problems occurring in network. PCF is not part of the Wi-Fi Alliance's interoperability standard and is not used.

3.3.2 Distributed Coordinated Function (DCF)

DCF is an asynchronous data transmission function and is widely used. In DCF every node has to compete to gain access to the channel resources. DCF uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) with binary exponential back-off algorithm.

3.3.2.1 CSMA/CA operations in DCF

Before a node transmits data, it first senses the shared media. If channel is busy it waits for an exponential back off interval and senses the channel again. On finding the channel idle, it waits for a period of time called “Distributed Inter Frame Spacing (DIFS)”. This wait period is to prevent collision when multiple nodes attempt to transmit at the same time as soon as they sense an idle channel. The exact length of DIFS is randomly selected from the range of values defined by Contention Window (CW). After DIFS, if channel is idle again, a Request to Send (RTS) frame is sent to receiver node to ensure no hidden node problem occurs. On receiving RTS and observing channel is idle, receiver node replies with a Clear to Send (CTS) frame which is broadcast to all nodes in media that channel will be busy for a specified amount of time. The desired data is being transmitted by the transmitter node to the receiver. The receiver responds with the ACK and successful transmission is achieved.

DCF works fine when considering all the application packets are equal in value and there is no need of QoS. DCF cannot differentiate QoS tagged packets and all tagged packets arriving from the wired LANs are treated the same way. This may affect communication of delay sensitive voice and video applications which are prioritized in WLANs.

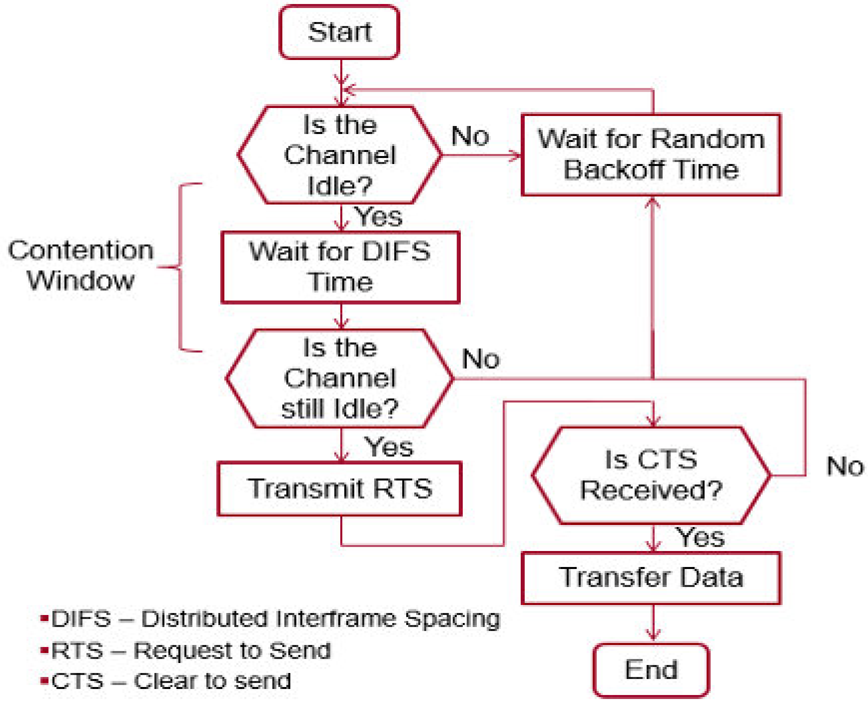


Figure 4 Carrier Sense Multiple Access with Collision Avoidance

3.3.3 Hybrid Coordination Function (HCF)

End-to-end QoS is very important requirement in many data networks, and DCF based Wireless LAN fails to provide this desired service by not understanding tagging of the wired LANs. In 2005 Hybrid Coordination Function (HCF) was proposed in 802.11e amendment which incorporates QoS methodology of wired LANs into wireless LAN. HCF implements Enhanced Distributed Channel Access (EDCA) which is a modified form of CSMA/CA and provide access to the channel resources based on application preferences. These preferences are collected from Quality of Service (QoS) tag of wired LANs. In this project the scope of wired LANs is kept limited to the Type of Service (ToS) based QoS.

3.3.3.1 Type of Service (ToS)

Applications used in the networks are different in characteristics from one another. For example voice and video applications are jitter and delay sensitive whose packets are of constant size and are being generated with a constant rate. While File transfer or E-mail traffic can resist delay and jitter. Their packet sizes vary with the TCP window size, and their origination might be in bursts of packets. In wired LAN, QoS (Quality of Service) is ensured by classifying and categorizing packets based on their characteristics. Then each traffic packet is tagged in Type of Service (ToS) field in the IP header (shown in Table 4) based on their class.

<table>
<tr><td>Ver.</td><td colspan="2">Header Length</td><td>Type of Service</td><td colspan="2">Total Length</td></tr>
<tr><td colspan="4">Identification</td><td>Flags</td><td>Offset</td></tr>
<tr><td colspan="2">Time To Live</td><td colspan="2">Protocol</td><td colspan="2">Checksum</td></tr>
<tr><td colspan="6">Source Address</td></tr>
<tr><td colspan="6">Destination Address</td></tr>
<tr><td colspan="6">Options and Padding</td></tr>
</table>

Table 4 IP header format

For tagging of packets only lowest 3 bits are used of the ToS field as given in Table 5. Based on these tags, packets are given order of precedence at each hop it traverses in the network. Voice and video applications having the higher tags are given higher order of precedence over other applications and this order of precedence is controlled by QoS policies. Creating favorable QoS polices for voice and video application circumvents the delay and jitter problem in wired networks.

ToS Bit value	**Traffic Type**
001	Background
010	Standard
000	Best Effort
011	Excellent Effort
100	Streaming Multimedia
101	Interactive Multimedia
110	Interactive Voice
111	Unreserved

Table 5 Type of Service tags

3.3.3.2 Enhanced Distributed Channel Access (EDCA)

In EDCA all incoming ToS tagged traffic packets are classified into 4 Access Categories (ACs) as shown in Table 6. Voice and video applications are assigned highest ACs while other applications are assigned lower AC. Based on level of access category of a packet, packets wait for an interval called Arbitrated Inter Frame Spacing (AIFS). AIFS is specified by minimum and maximum contention window values of AC (CWmin & CWmax as given in Table 6). The CWmin & CWmax values of higher ACs packets is very low giving it less waiting time compared to the low AC packets, As a result chances of higher AC packet to access channel becomes greater.

Once a higher AC packet of voice and video accesses the channel, EDCA creates a TXOP (Transmit Opportunity) interval which specifies that higher AC packet can hold channel for a considerable amount of time and can transmit multiple packets during that instance. Table 6 show the default TXOP value for ACs. The minimum AIFS time and TXOP overall give considerable advantage to the voice and video applications in channel access.

ToS Tag	**AC**	**CWmin**	**CWmax**	**TXOP**
Background(001), Standard(010)	Background	15	1023	0
Best Effort(000)	Best Effort	15	1023	0
Excellent Effort (011) Streaming Media (100) Interactive Media (101)	Video	7	15	3.008 ms
Interactive Voice (110) Unreserved (111)	Voice	3	7	1.504ms

Table 6 Access Categories

4 OPNET Architecture Design

To simulate EDCA and its involvement in end-to-end QoS, The network model is created in OPNET 16.0 using standard library models. Simulations are carried to obtain results and 4 scenarios of the network are created for simulation to demonstrate comparison between no QoS based network, network with wired LANs QoS only, EDCA enabled WLAN network and EDCA enabled WLAN network with non-default TXOP for voice AC.

4.1 Network Topology

The design of the campus network is created in such a way that the major portion of LAN is based on wireless communication. The campus LAN comprises of 5 Access Points (AP) covering hexagon shaped regions. All APs provide services over the same IP subnet and SSID (Signal Set Identifier) using Extended Service Set (ESS). APs are connected to the switch and server where all application services are terminated.

We profile this campus network to be of an office by generating traffic of following applications.

1) Database Access (Heavy).
2) E-mail (Heavy).
3) File Transfer (Heavy).
4) Telnet (Light).
5) File Print (Light).
6) Web Browsing (Heavy)
7) Video Conferencing (Light).
8) Voice over IP (PCM Quality).

The generated traffics are divided into 2 major categories.

1) Video/Audio traffic.
2) TCP traffic.

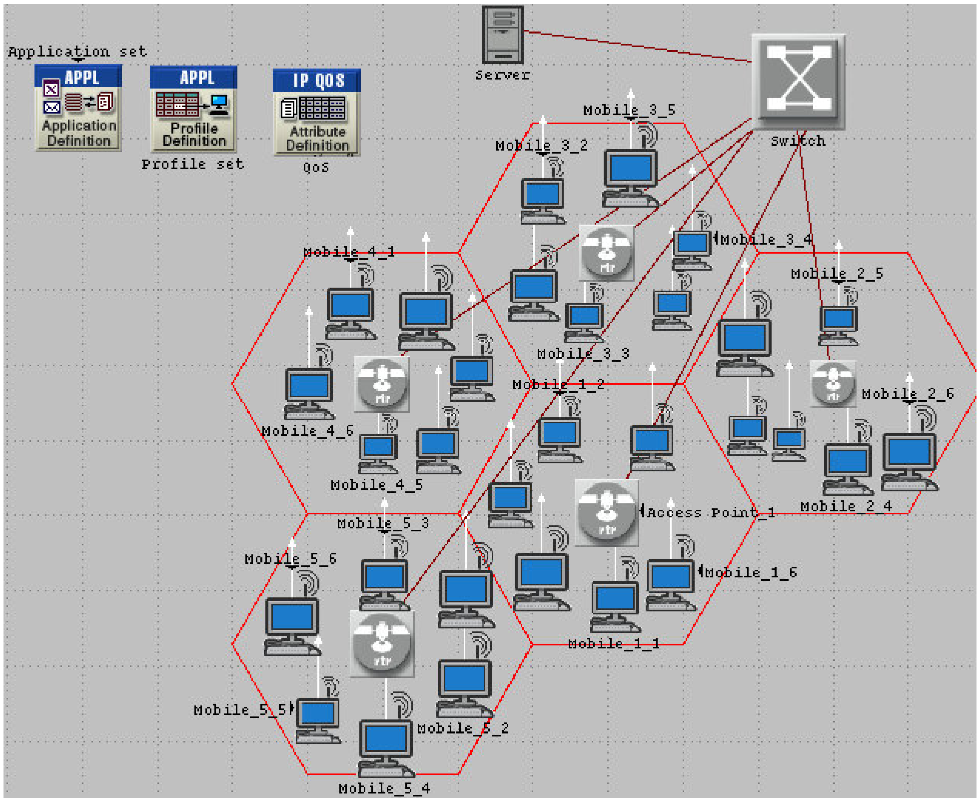


Figure 5 OPNET network architecture design

4.2 Configurations

4.2.1 Configuration of Access Points

5 Access points are configured to operate at 54 Mbps on 802.11g standard at frequency of 2.4 GHz. Respective Access Points are assigned unique Basic Service Set Identifier so they are recognized by their stations. Keeping them within single subnet make them to be part of same network. The consecutive residing Access Points are assigned channel 1, 6 and 11 to prevent overlap of signals.

Attribute	Value
Wireless LAN MAC Address	Auto Assigned
⊟ Wireless LAN Parameters	(...)
BSS Identifier	4
Access Point Functionality	Enabled
Physical Characteristics	Extended Rate PHY (802.11g)
Data Rate (bps)	54 Mbps
⊞ Channel Settings	Channel 1
Transmit Power (W)	0.00322
Packet Reception-Power Thr...	-95
Rts Threshold (bytes)	None
Fragmentation Threshold (b...	None
CTS-to-self Option	Enabled
Short Retry Limit	7
Long Retry Limit	4
AP Beacon Interval (secs)	0.02
Max Receive Lifetime (secs)	0.5
Buffer Size (bits)	256000

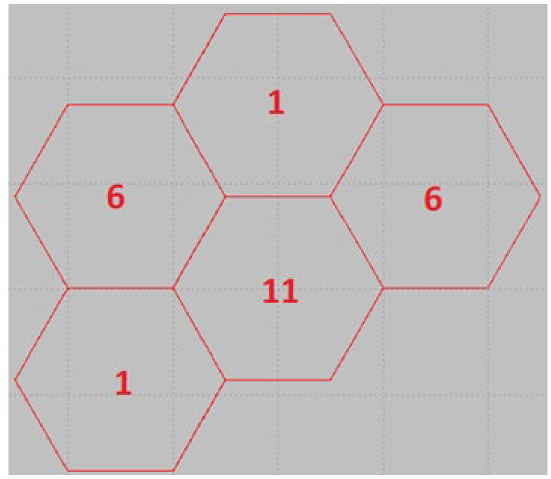


Figure 6 Example of Access Point 5 configuration and channels assigned to the cells at 2.4GHz

4.2.2 Configuration of Generated Applications

Within the range of every Access point 6 stations are added which are generating traffic towards server of following applications

S No.	Applications	Traffic Generated
1.	Database Access (Heavy)	Uniform
2.	E-mail (Heavy)	Uniform
3.	File Transfer (Heavy)	Uniform
4.	Telnet (Light)	Poisson
5.	File Print (Light)	Uniform
6.	Web Browsing (Heavy)	Poisson
7.	Video Conferencing (Light)	Constant
8.	Voice over IP (PCM Quality)	Constant

Table 7 Traffic Applications and their generated patterns

4.2.3 Configuration of QoS in Scenarios

Four scenarios are created for the simulation and every scenario is upgraded form of the previous one.

Scenario-1 Configurations: Simulation is run on with no QoS involved. All packets are served with first in first out (FIFO) scheme.
Scenario-2 Configurations: Applications generated traffic are tagged in the packet header following ToS based tagging scheme. Throughout the network, at all the Ethernet interfaces, packets are specified order of preference based on queuing policies set for all these tags. In this

project we use the default queuing policies on the interfaces. Following are ToS tags assigned to the application packets.

S No.	Applications	ToS Tags assigned
1.	Database Access (Heavy)	Standard (010)
2.	E-mail (Heavy)	Best Effort (000)
3.	File Transfer (Heavy)	Background (001)
4.	Telnet (Light)	Best effort (000)
5.	File Print (Light)	Standard (010)
6.	Web Browsing (Heavy)	Background (001)
7.	Video Conferencing (Light)	Interactive Multimedia (101)
8.	Voice over IP (PCM Quality)	Voice (110)

Table 8 ToS tags assigned to the applications

Scenario-3 Configurations: EDCA is enabled on all Access Points, and based on Table 6 the access categories are assigned to the ToS tagged packets. The method to enable EDCA on APs is given below.

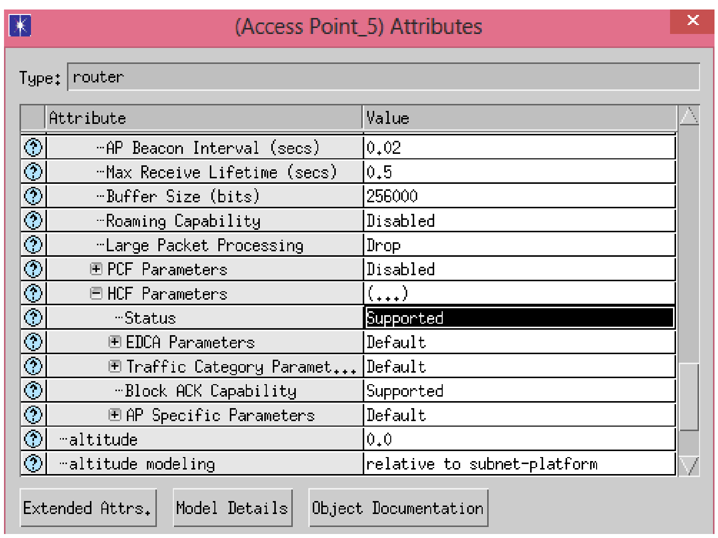


Figure 7 Enabling EDCA on Access Points

Scenario-4 Configurations: Value of transmit opportunity (TXOP) for the voice is slightly modified to 3.008ms from its default value of 1.504ms.

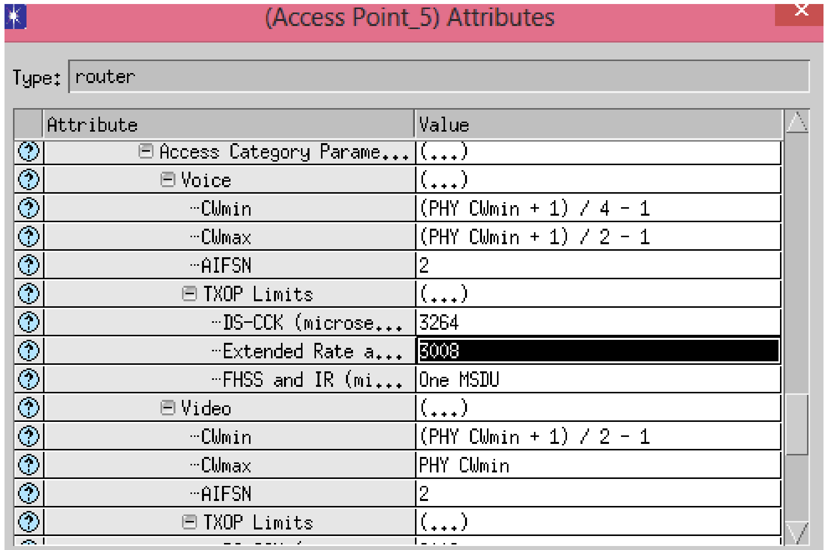


Figure 8 Changing default TXOP value for Voice AC from 1504 to 3008 µsec

5 Simulation Results

In OPNET the scenarios are simulated for 15 minutes which is sufficient time to determine operations of Enhanced Distributed Channel Access. The resulting graphs which are collected are in time average.

5.1 Media access delay of Access Categories (ACs)

In scenario-3 (EDCA enabled) the delay in accessing wireless media is investigated for Access Categories (ACs). As given in the figure below, Background and Best Effort data suffer more delay compared to the high priority ACs of Voice and Video. This figure ensures that Enhanced Distributed Channel Access is operating in the desired manner.

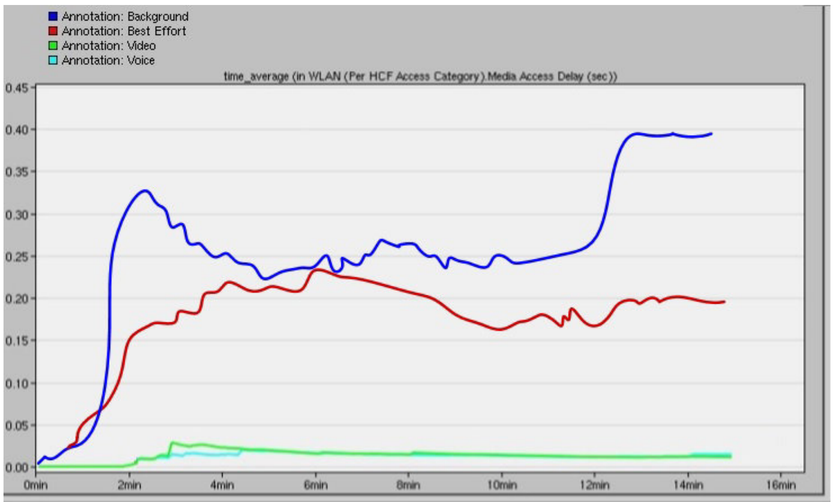
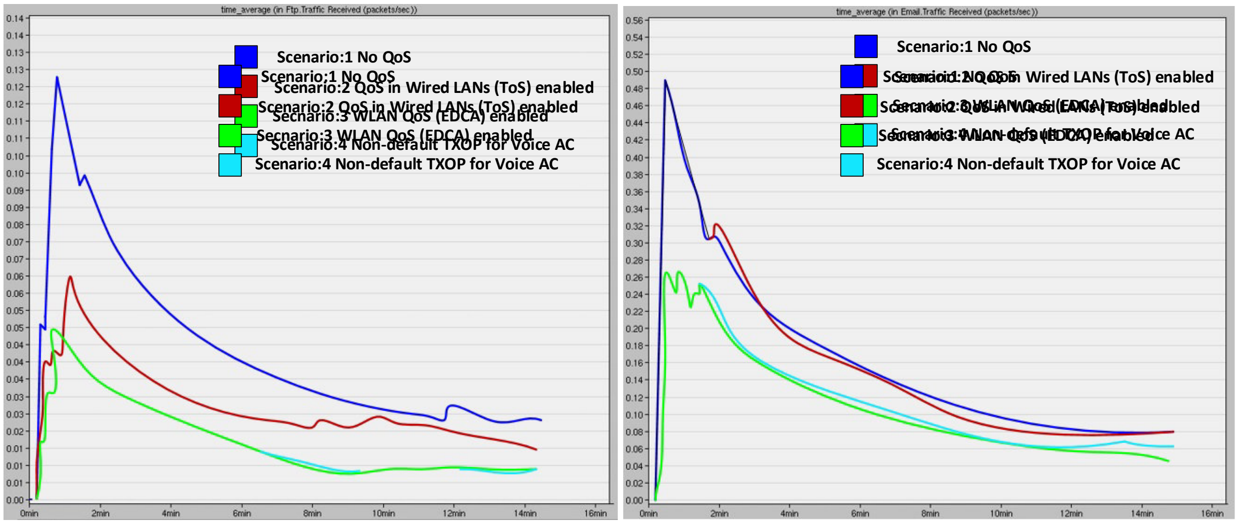


Figure 9 Comparison of channel access delay between Access Categories

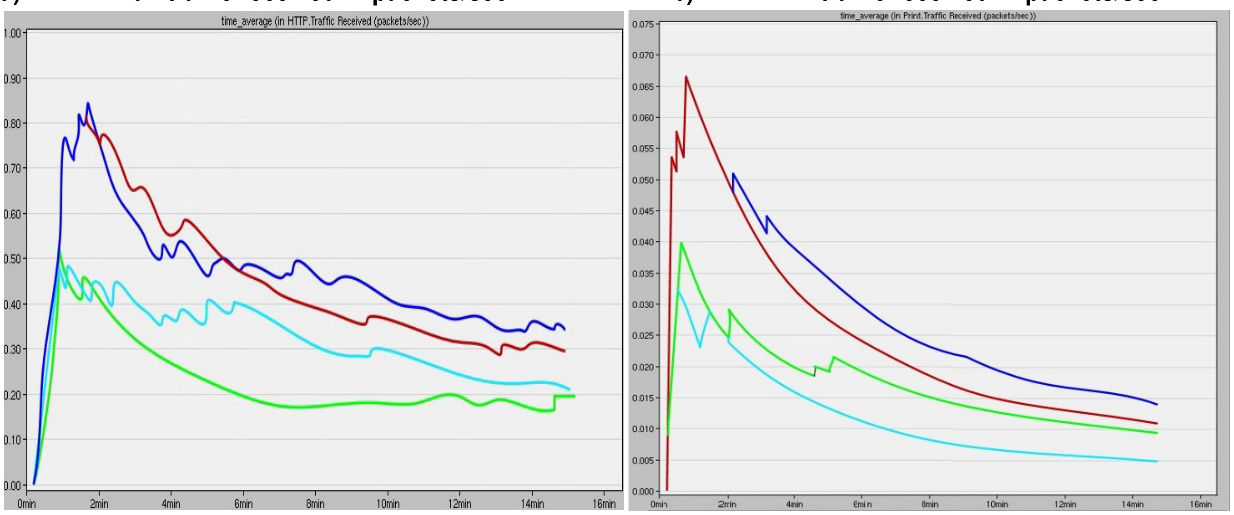
5.2 TCP Traffic

In the simulation, different TCP based applications are generated in competition to the Voice/Video traffic. The TCP traffic in scenario-1 (no QoS scenario) has dominance over the wireless channel and more TCP data is being transmitted and received, but as soon as different stages of QoS in wired and wireless LANs are enabled in scenario-2, scenario-3 and scenario-4, reception of TCP traffic is subsequently reduced.

In figures given below it is clearly visible that extending the effect of QoS on the network subsequently reduces the reception of TCP data traffic in packets/sec.



a) Email traffic received in packets/sec **b) FTP traffic received in packets/sec**



a) Print traffic received in packets/sec **b) HTTP traffic received in packets/sec**

Figure 10 Traffic received of a) Email, b) FTP, c) Print and d) HTTP applications in simulation

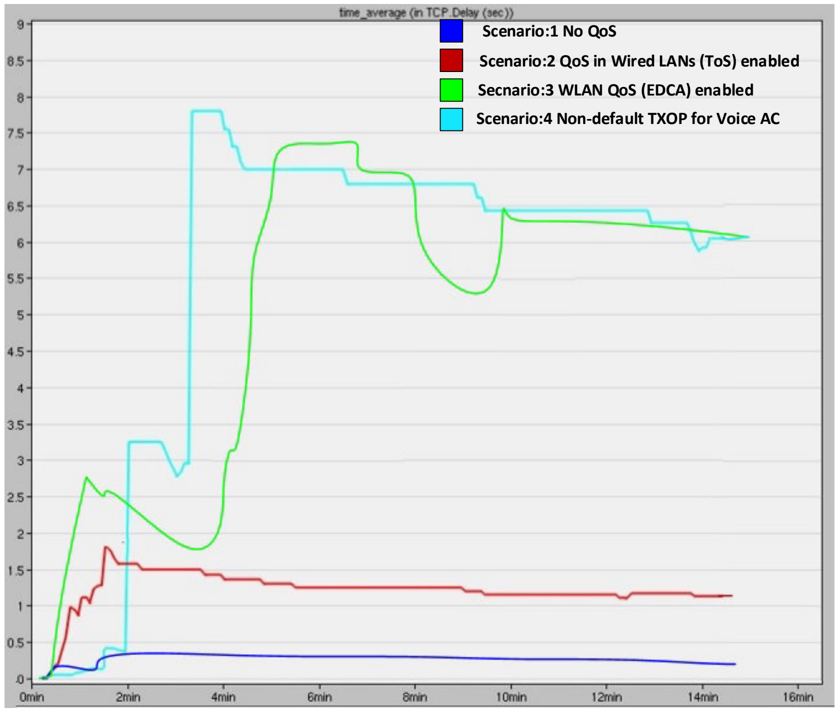


Figure 11 TCP segment delay in seconds

Figure 11 shows that by enabling QoS and prioritizing voice and video traffic TCP applications over all get delayed.

5.3 Video Conferencing Traffic

In this simulation interactive video conferencing is being added in which 2-way traffic is simultaneously propagated between nodes and server in both directions. Now as the QoS is employed in wired and wireless LANs, the video conferencing traffic end-to-end delay and number of packet received are improved which are clear from below figure 12 and 13.

In the figure 12 and 13 the Scenario 4 graph tilts towards more end-to-end delay and less traffic reception compared to the graphs of scenario 3. The reason of this degradation is because voice traffic is now having same TXOP as video conferencing traffic and is now competing in channel access.

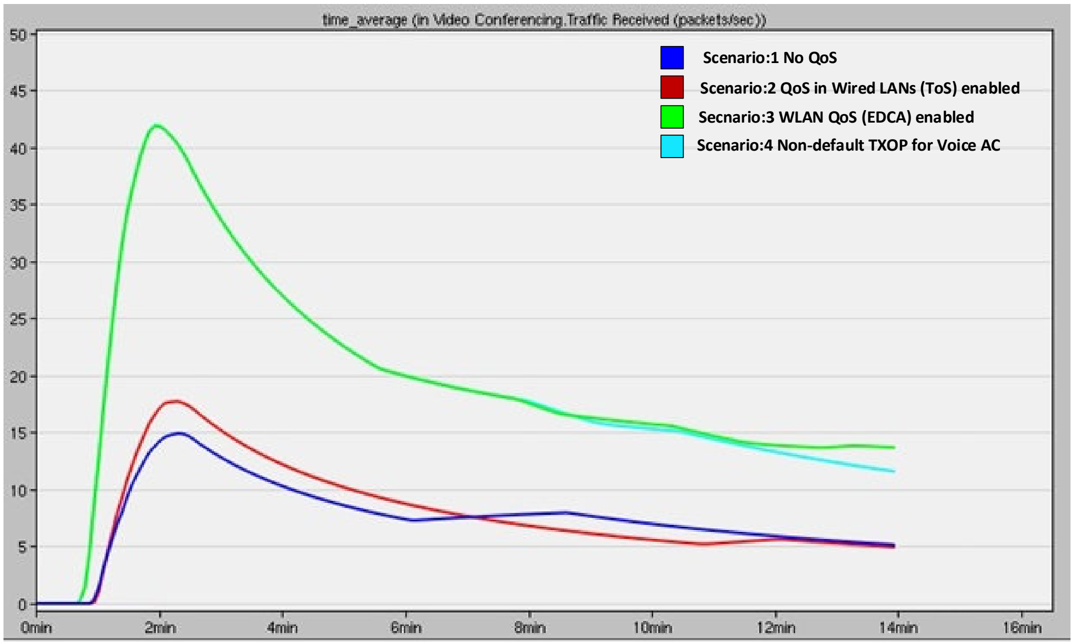


Figure 12 Video Conferencing traffic received packets/second

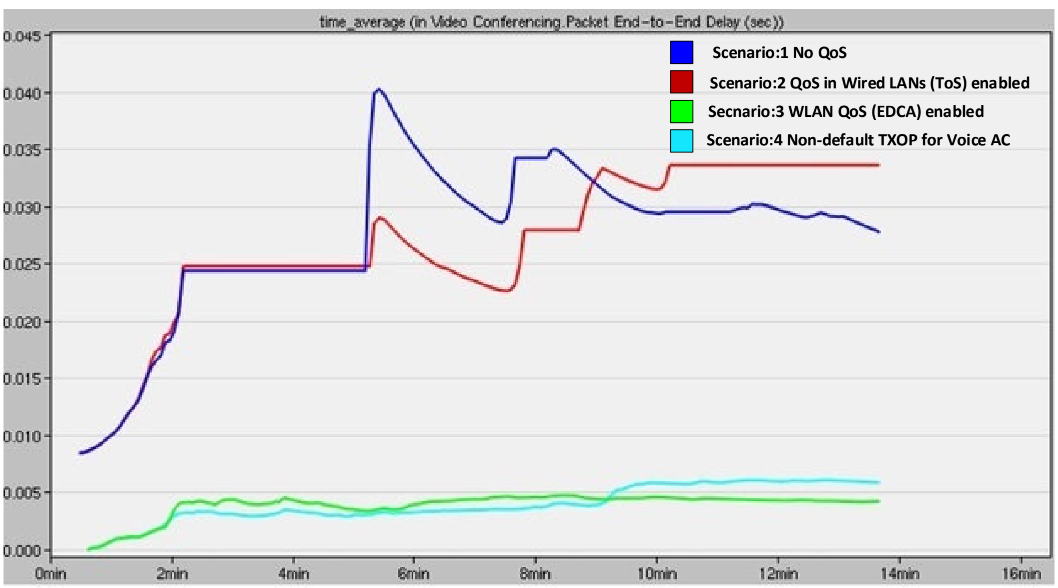


Figure 13 Video Conferencing End-to-End Delay

5.4 Voice Traffic

In communication networks, VoIP is always given highest level of preference because of its characteristics. VoIP packets are small and they take constant 80 kbps of the channel after being encoded using G.711. EDCA provides quick access to these packets via shorter AIFS over wireless media, and then the channel is also allocated using TXOP for a specified amount of time so that more and more packets are transmitted at once. As a result voice packets suffer less jitter and end-to-end delay. Hence more voice packets are received per second. In scenario 4, the default TXOP value is increased for VoIP data. From graphs it is clear that slight improvement is achieved in end-to-end delay and jitter but overall packets received per second are reduced because now after Video Conferencing, Voice is also demanding channel allocation for longer time. The channel is busy most of the time to accommodate new calls. Also changing the default TXOP value adversely affects the video access category data as the received video conferencing data is slightly reduced as per figure 12 and end-to-end delay is increased as per figure 13.

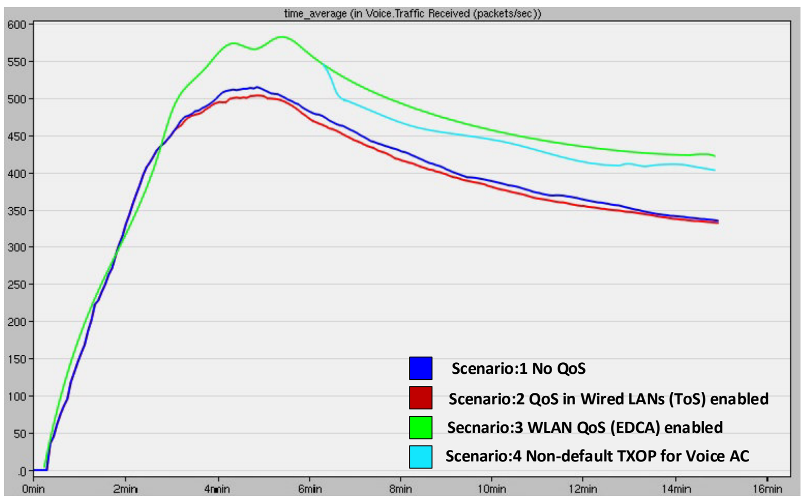


Figure 14 Voice traffic received (packets/second)

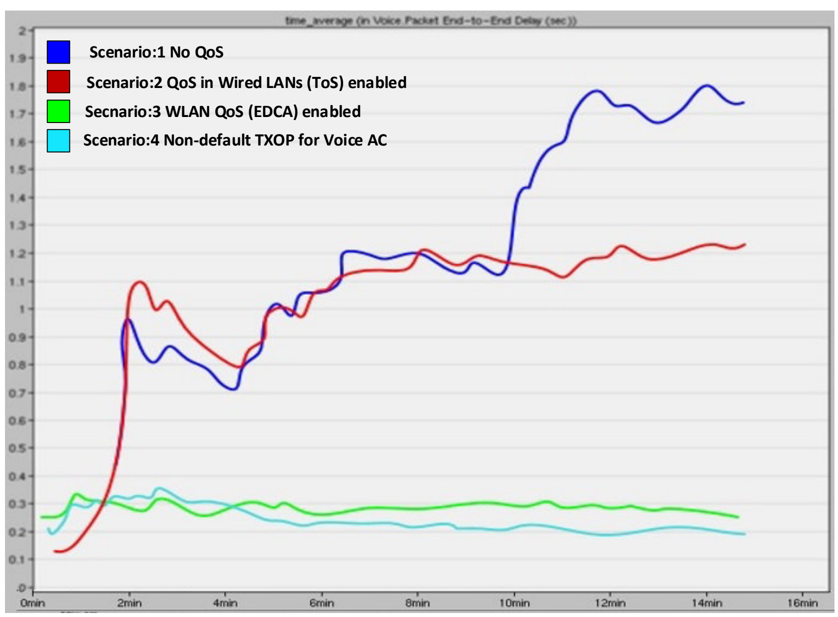


Figure 15 Voice traffic end-to-end delay

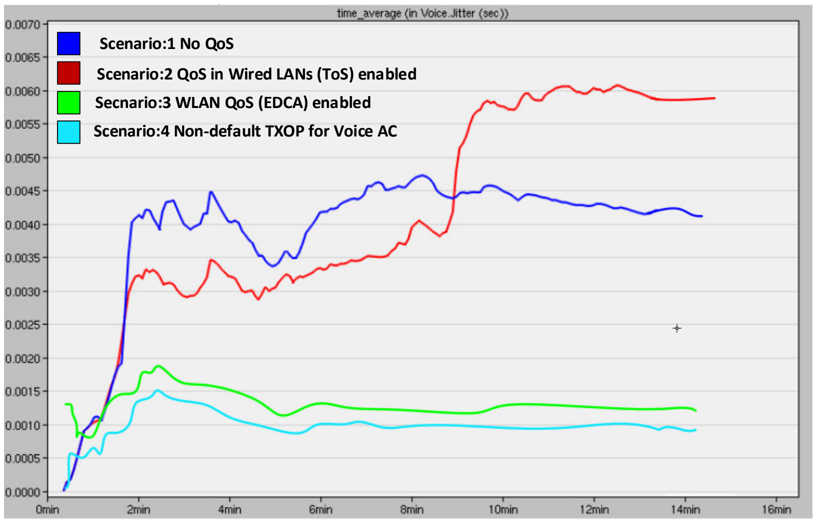


Figure 16 Voice traffic jitter

6 Related Work

Numerous works have explored the capabilities of EDCA for WLAN in OPNET simulations, but one particular paper, [7], was useful in helping us understand our simulation results. With different approach to similar problems, we were able to reach the same conclusion stated in previous works.

7 Future Work

In this project our objective is to observe the response of different applications to a QoS and non-QoS based channel access in WLANs using standard based techniques. Hence simple topology is created with very few parameters of QoS, EDCA and applications are considered. Following are some assumptions made to make operations of network simple:

- Nodes are static (no mobility) so they remain associated to the same Access Point all the time.
- Nodes communicating at 54 Mbps only.
- All nodes generate Video Conferencing and VoIP traffic.
- No environmental aspects affecting wireless communication such as reflection, refraction, scattering and Doppler shift are considered.
- Only ToS based QoS was considered in network with 1 SSID and 1 subnet for all the nodes.
- All interfaces QoS profiles were set to default.

In future simulation can be brought to a precision of a real time enterprise network by taking contribution of the above mentioned assumptions into consideration in a network model.

8 Conclusion

The aim of this project is to highlight and understand the methodology of EDCA of incorporating the QoS of wired LANs into wireless LANs. Traditionally CSMA/CA based WLANs serves as a broken link in the end-to-end QoS architecture of the network as they don't understand QoS. EDCA is proposed as a solution in which packets tagged in wired LANs in ToS sub-field of the IP packet are classified into access categories. Based on Access categories the shared wireless media is allocated to the nodes with specified order of preference.

Through results of this project, it is analyzed that even in the worst case scenario where wireless is the dominant portion of LAN, EDCA performs as expected by providing compatible traffic pattern as wired LAN. And due to this positive response, the end-to-end QoS in the network is achieved by giving the desired improvements to the delay sensitive applications such as voice and video over the TCP based applications.

Also it has been observed in the simulation that the values of various parameters of EDCA, such as contention window size and TXOP of the Access Categories, are the best fit for the network. Deviating any of these parameters from default specified values will overall produce worst results in traffic patterns.

9 References

[1] K. Alutaibi and Lj. Trajkovic, "Performance analysis of VoIP codecs over Wi-Fi and WiMAX networks," *OPNETWORK 2012*, Washington, DC, Aug. 2012.

[2] C. Powell, “An Enhanced Distributed Channel Access Deficit Round-Robin Scheme for IEEE 802.11E Wireless Network,” UBC Retrospective Theses Digitization Project, University of British Columbia, Vancouver, BC, 2004.

[3] F. Peng, B. Peng, and D. Qian, “Performance analysis of IEEE 802.11e enhanced distributed channel access,” *Communications*, IET, vol. 4, no. 9, pp. 728–738, Apr. 2010.

[4] J. Misic, R. Saeed, and B. Misic, “ Analysis of impact of TXOP allocation on IEEE 802.11e EDCA under variable network load,” *IEEE Transaction on Parallel and Distributed Systems*, vol. 23, no. 5, pp. 785-799, May 2012.

[5] X. Dongxia Xu, T. Sakurai, and H. L. Vu, “An access delay model for IEEE 802.11e EDCA,” *IEEE Computer Society*, vol. 8 no. 2 pp. 261-275, Feb. 2009.

[6] Roshan, P. and Leary, J. 802.11 Wireless LAN Fundamentals, Indianapolis, Indiana: Cisco Press; 2003.

[7] S. Sehrawat, R. P. Bora, and D. Harihar, “Performance Analysis of QoS supported by Enhanced Distributed Channel Access (EDCA) mechanism in IEEE 802.11e”, *IAENG International Journal of Computer Science*, 33:1, IJCS_33_1_6, Feb 2007.

[8] *Cisco Building Cisco Multilayer Switched Networks (BCMSN) Student Guide Version 3.0* (2 ed.). (2005). San Jose: Cisco Publishers.

[9] Wikipedia contributors. (2014, April 14). *Wireless LAN*. [Online]. Available: http://en.wikipedia.org/wiki/Wireless_LAN

[10] Gast, Matthew . 802.11ac, A survival guide. Sebastopol, California, USA: Orielly, 2013.

10 Appendices

10.1 Acronyms

AC – Access Categories

AP – Access Points

CSMA/CA – Carrier Sense Multiple Access with Collision Avoidance

CW – Contention Window

DCF – Distributed Coordination Function

EDCA – Enhanced Distributed Channel Access

HCF – Hybrid Coordination Function

LAN – Local Area Network

QoS – Quality of Service

ToS – Type of Service

TXOP - Transmit Opportunity

WLAN – Wireless Local Area Network