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WLAN performance evaluation in different wireless access techniques (DCF, PCF, HCF)

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ABSTRACT

IEEE 802.11x Wireless Local-Area-Network (WLAN) considered a powerful solution for the last mile wireless broadband (BB) access. WLAN becomes important element in 4G and 5G mobile networks because it can provide services to mobile users in areas not covered by eNBs. However, the 802.11 legacy protocol doesn't support delay-sensitive services like VoIP because it adopts the best-effort method. In 2001 IEEE 802.11e standard was proposed to deploy QoS with new access techniques introduction. There are many parameters related to MAC layer which affect the WLAN network performance from the prospective of delay, and throughput. This study presents performance evaluation of voice traffic and FTP traffic in IEEE802.11 legacy protocol WLAN and IEEE802.11e WLAN via OPNET computer simulation. Network performance will be tested against different MAC access protocols and different MAC parameters**.**

Keywords: WLAN, MAC, DCF, PCF, HCF, ETE, QoS

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1. Introduction

IEEE 802.11 is the deface to standard for the widely deployed WLANs [1-3]. Since its start in 1997, data rates increased from megabit parsec. (Mbps) to gigabit per sec. (Gbps),previously achieved by cable technology [4, 5].

WLAN adopted IEEE802.11 standard which specifies two layers in WLAN deployment Media-Access Control (MAC) and Physical (PHY) layers. PHY layer specifies the signaling characteristics and modulation method used in transmission through wireless channel. These specifications vary from one WLAN protocol to another (i.e. IEEE802.11, IEEE802.11a, IEEE802.11b, and IEEE802.11n). MAC layer function is transferring packets across a shared wireless media. The MAC protocol specifies a channel-access mechanism to make several stations to communicate without collision between each other [6]. In IEEE802.11 protocol doesn't support QoS due to lack of guarantee latency of delay-sensitive applications (e.g. video ,and voice).IEEE established Group E to enhance legacy 802.11 protocol to achieve the quality requirements, the new standard name is IEEE802.11e [7, 8]. Many different organizations adopted IEEE802.11 protocols. The essential features of 802.11 WLANs are their robustness against errors and simplicity. Using the 2.4GHz (ISM band) , the 802.11b version can provide up to 11Mbit/s.802.11a version can provide data rate around 54Mb/sby using OFDM technique in the 5GHz band. 802.11g and 802.11n is a common standard in WLAN networks todays with 54 Mb/s, and up to 600 Mb/s [9].VoIP is the main application these days in Internet. It provides the following two features versus voice telephone networks. First, VoIP can improve bandwidth (BW) efficiency by make use of compression techniques and BW sharing in data networks. Second, new multimedia applications that deliver new services by combining file sharing, video, with traditional voice. WLAN today considered a part from mobile network (4G and 5G) to guarantee full coverage at anywhere [10-12].In WLAN several parameters are configurable and has a large impact on network performance, such us:

- Access point properties: Antenna Gain, Modulation, Wireless Card, Standard, and Frequency, Transmit Power and Coverage.
- Number of users: Channel access competition.
- Mobility of users: Specifies whether the mobile node should switch to Access Points (AP) with higher signal strength.
- Type and rate of traffic: Best effort or Multimedia.
- In this paper a simulation to WLAN network is conducted by OPNET [13]to present the effects of varying MAC parameters and changing access techniques on the WLAN performance parameters from the view of delay, jitter (delay variation), and throughput. In section II, WLAN MAC is briefly reviewed. In Section III, 802.11e standard description is presented. Section IV presents the simulation model and results. Section V concludes the study.

2. WLAN MAC

IEEE802.11 data link layer defines two access methods for data packets: Point-Coordination Function (PCF) at which AP controls all wireless transmissions and Distributed-Coordination Function (DCF)which use Carrier-Sense Multiple Access/Collision Avoidance (CSMA/CA). PCF and DCF models are multiplexed in a super-frame as declared in Fig.1. This super-frame is formed of contention-free period (PCF CFP) followed by a contention period (DCF-CP). In the start of super-frame, AP transmits beacon messages to deliver management and control information to wireless stations and make them know the beginning of CFP. Wireless stations use CFP beginning information to perform AP association. When the wireless station will be scheduled by PCF it must has AP association, which is required for applications that need QoS deployment. Priorities for packets are implemented using different Inter-Frame Spaces (IFSs) lengths:

- SIFS (Short Inter-Frame Space): used for high priority frames transmission (Shortest IFS) of data frame’s acknowledgements, clear-to-send/ready-to-receive (CTS/RTS) frames, time between PCF/DCF fragments (except the first fragment in a data burst)[14].
- PIFS (PCF- Inter-Frame Space): Any PCF wireless terminalcan transmits its frames after PIFS expires. It is larger than SIFS
- DIFS (DCF- Inter-Frame Space): After DIFS expires, the DCF station transmits its frames. It is larger than PIF.

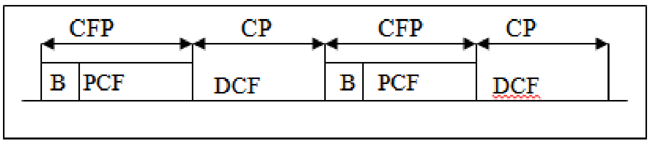

Figure1. DCF /PCF super-frame

2.1 Distributed coordination function (DCF)

When a wireless terminal uses DCF method to access the medium, it senses the medium first; if idle it sets a DIFS interval in to down counter and checks the channel again after this counter expire. If the medium still idle the wireless terminal sends the frame. The destination terminal determines the last field in the frame (checksum value) and checks the correctness of the received frame. If it correct frame, the destination terminal waits SIFS period and sends ACK frame to the transmitting wireless terminal, which indicate successful transmission as declared in Fig. 2.

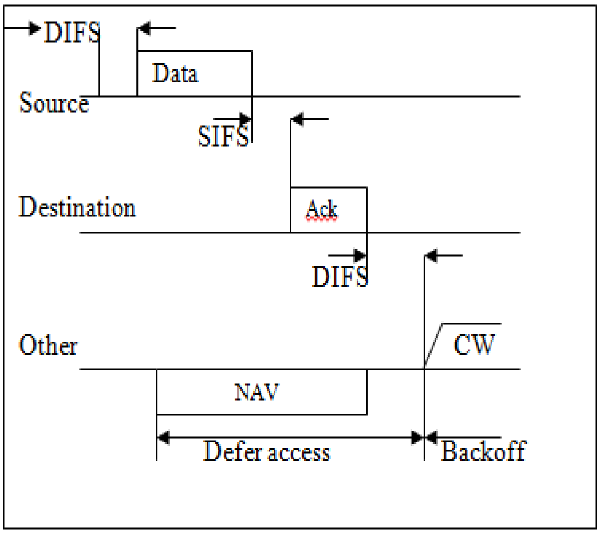

Figure 2. MPDU transmission

When the wireless terminal transmits a frame, it uses a certain field in the wireless frame header to make other wireless terminals determine when the channel will be free again. All wireless terminals hearing this field adjust a certain variable called Network-Allocation Vector field (NAV) based on this value, this period includes ACK time and SIFS. If the transmitting wireless terminal checks the medium and found it busy; the wireless terminal waits until the medium becomes free for a DIFS interval, then calculates a random back-off time called collision window [15, 16]. Collision window interval is an integer number related to time slots number [17, 18]. DCF method provides fairness betweenthe wireless terminals; because each terminal must contend for the channelafter every packet transmission. DCFdoesn't support delay sensitiveservices. All wireless terminals have equalchance of get access to the medium after each DIFSinterval, so delay requirements can't be guaranteed for real time applications like voice [19].

3. IEEE 802.11e

IEEE802.11e adds new access method called Hybrid-Coordination Function (HCF). This methodcontains two new access techniques: controlled-channel access mechanism (HCCA), and contention-based channel access (Enhanced Distribution Channel Access (EDCA)). The main characteristic in HCF is the introduction of Transmission Opportunity concept (TXOP) which is a time period where a QoS aware station (Q-STA) can send a frame burst. TXOP maximum value called TXOP-limit, this value is assigned by QoS enhanced Access Point (Q-AP) to make delay control [20, 21]. EDCA implements four different buffers (i.e. data queues) called Access Category (AC) in every QoS aware terminal. These queues for eight user data priorities (UP) presented in IEEE802.1D standard, declared in Fig.3. The basic function of EDCA is to supporttraffic differentiation. Every AC considered independent DCF terminal with dedicated access parameters (CWmax[AC], CWmin[AC], TXOP-limit[AC], AIFS[AC]) that are periodically broadcasted by AP during the beacon interval. EDCA introduce two techniques to support traffic differentiation: the first one is to use new Inter-Farme Space (IFS) called Arbitration IFS(AIFS) for each AC instead of DIFS. The AIFS[AC]is calculated by:

AIFS[AC] = AIFSN[AC]* Slot_Time + SIFS

Where AIFSN[AC] is the arbitration IFS number. The second technique allocates different sizes of collision window for each AC. High AC priority has small window size which make frame belonging to this AC being transmitted before other frames related to different AC which has larger window size[22].

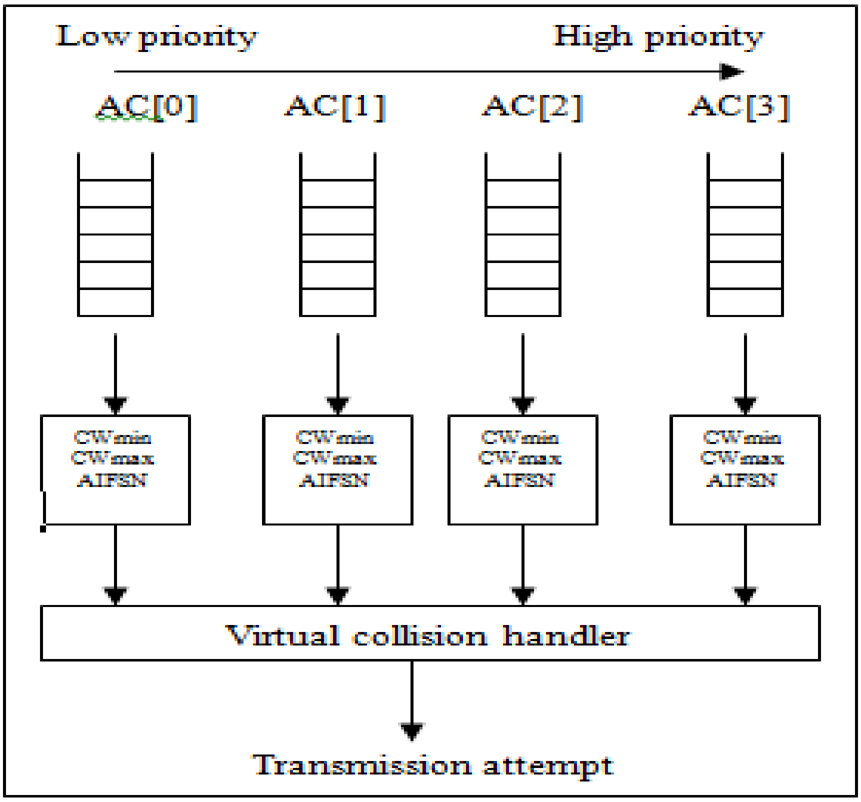

Figure 3. EDCA access categories

The backoff time is randomly chosen between (1, CW[AC]), when the backoff process is invoked [13]. Each AC in a QoS-aware terminal can send a QoS request to the AP, this request contains the traffic specification (TSPEC) of its application likepeak/mean data rate, maximum/mean frame size. When the AP receives the request, it makes admission control to determine if the request accepted or not. If the request accepted, it determines the duration for the admitted data to use the channel [21, 23]

4. Simulation and results

OPNET simulator provides a graphical interface for different network models for performance-evaluation of networks and distribution systems. The models consist of many different tools, each one focusing on specific aspects of the modeling task [24]. OPNET divides the modeled system into different layers with each layer having its function. Each layer has many sub-layers with different smaller tasks. OPNET consists of process domain, domain nodes, andnetwork domain [25, 26]. The OPNET simulation will presents IEEE 802.11b network with voice, and data wireless terminals. The performance parameters are delay, delay variation(jitter), and throughput. The wireless access delay is the total of contention periods of packets and queue time. Throughput is transmitted-bits number on the wireless channel. To eliminate the complexity, it is assumed the following items:

1-No hidden nodes in the simulated network.

2-Interference and noise from other networks are negligible.

3-Propagation delay on the simulated networkis negligible.

Fig 4 shows the topology of WiFi network which implement DCF access method, the WLAN topology is adhoc network which means that there is no AP in the network, so the network can't be connected with wired network. The network contains 10 wireless stations. Each wireless terminal transmit/receive the traffic to/from another station as noted in table 1.

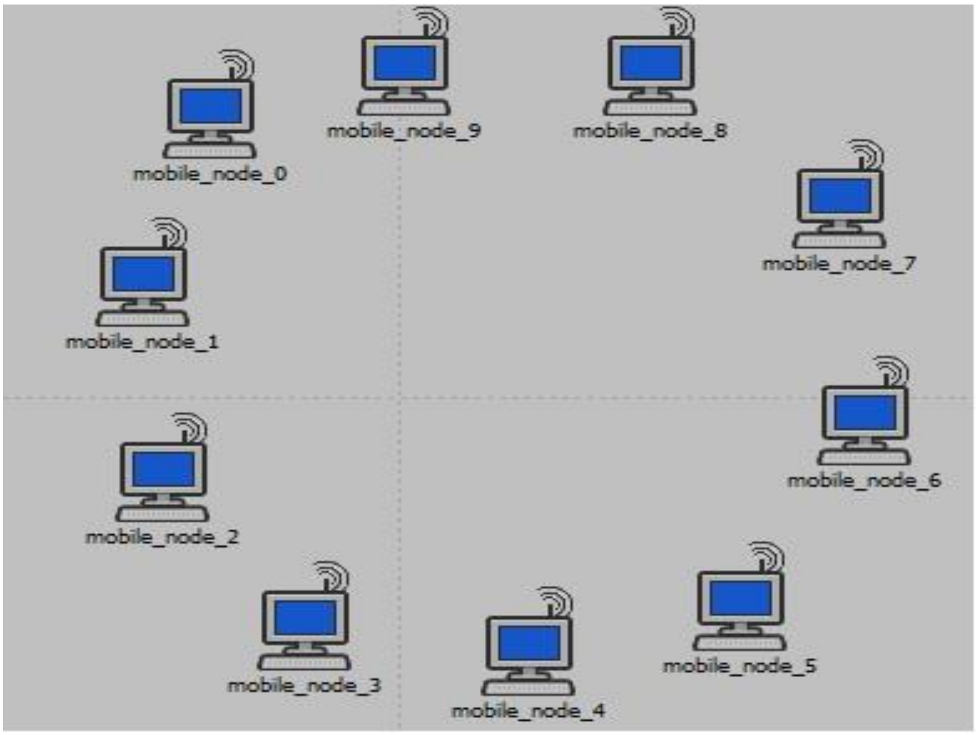

Figure 4. Adhoc network topology

Table 1. The wireless stations transmitter/receiver

Wireless station transceiver	Wireless station transceiver
Station 0	Station 1
Station 2	Station 3
Station 4	Station 5
Station 6	Station 7
Station 8	Station 9

The traffic parameters which listed as follows:
1-Packet size: uniform (200,1500) byte
2-Inter-arrival time: exponential (0.25) sec
3-Supported standard: 802.11g
4-Access method: DCF

The study will simulate different scenarios. First the network will be simulated to know the effect of varying the fragmentation threshold, and RTS threshold. Fig 5 shows the relation between different fragmentation thresholds and the average End-To-End (ETE) delay for wireless stations. From the figure it is concluded that by increasing the fragmentation threshold the delay decreased, this is normal result because when decreasing the fragmentation threshold, the transmitted frames will take longer time to be sent to the destination due to dividing frames to fragments separated by SIFS. When the fragmentation option is disabled (blue line) the average ETE delay is increased because of retransmitted packets in case of collision.

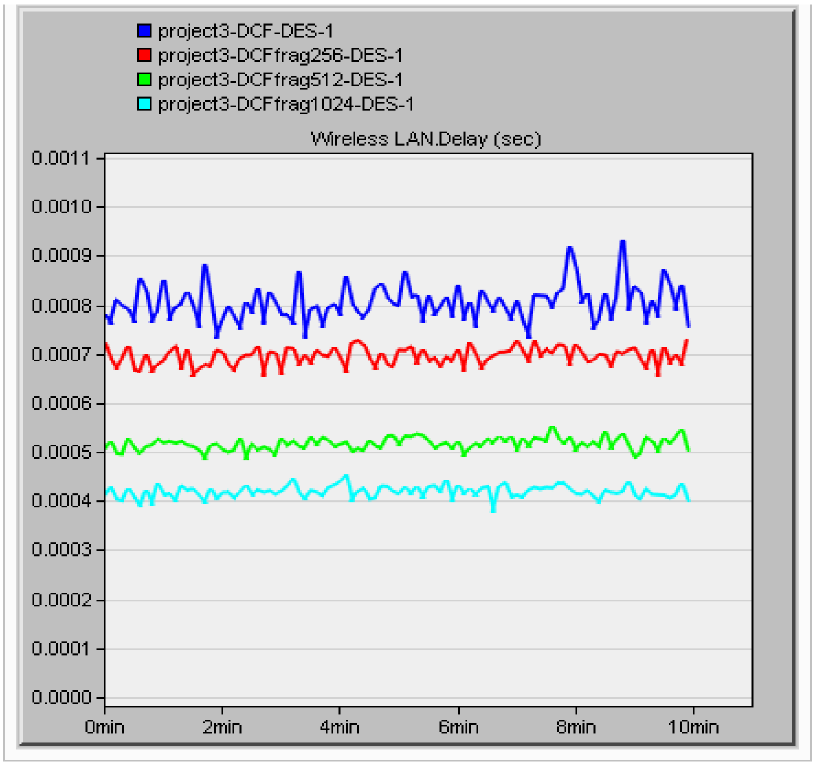

Figure 5. Wireless access delay vs. fragmentation threshold

Table 2. shows that the average delay versus the fragmentation threshold values.

Table 2. The average wireless access delay

Fragmentation threshold (byte)	Average packet delay (ms)
No fragmentation	0.8
256	0.7
512	0.5
1024	0.4

RTS/CTS technique used to eliminate hidden node problem. Fig 6and table 3 show RTS threshold variation versusframes delay, the figure declares that by enabling RTS option the average delay decreased 50 % and the result of varying the threshold is negligible in our topology, but generally by increasing the threshold the average delay is decreased, because the volume of introduced RTS/CTS packets are decreased.

Table 3. Lists the average delay versus RTS threshold

RTS threshold (byte)	Average packet delay (ms)
No RTS	0.8
256	0.41
512	0.39
1024	0.36

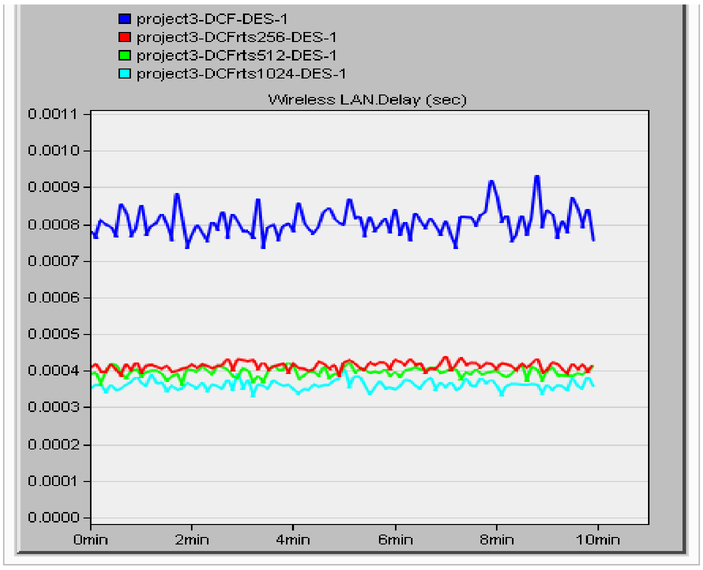

Figure 6. Wireless access delay vs. RTS threshold

Figure7. shows infrastructure topology which contains 3 WLAN stations connected to FTP server and voice stations through Access Point (AP).

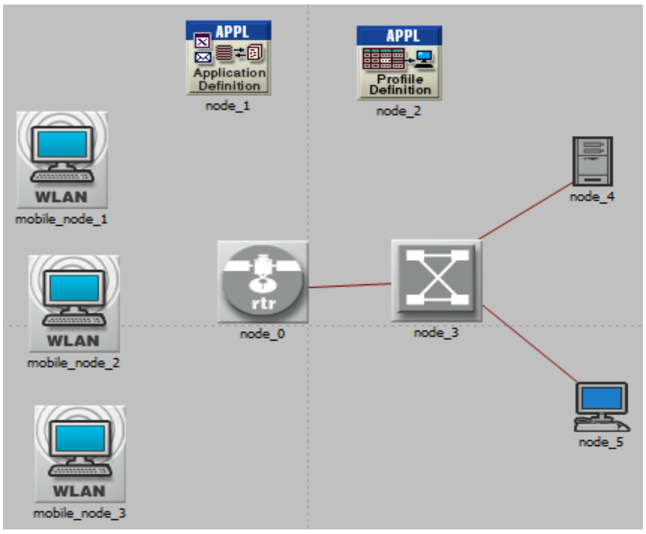

Figure 7. Infrastructure topology

The traffic parameters as follows:
Inter-request time: constant 7 sec
File size: 10 Mbyte
Voice Codec: G71

Figure8. presents the average delay for voice packets using DCF, and PCF techniques. The figure declares that the voice delay is variable in DCF because no differentiation between different services. By using PCF certain wireless terminal can be assigned to operate in this mode so can guarantee QoS to certain traffic. From the figure it can be notice the fixed voice delay when using PCF mode compared with variable delay using DCF (red line). This is because in PCF (red line) there are semi-fixed times for CFP which guarantee very small delay variation between packets, as presented in Fig. 9.

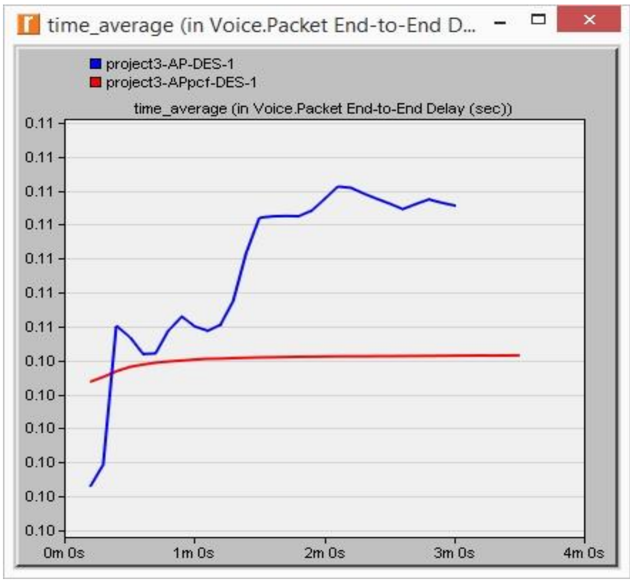

Figure 8. Voice delay in PCF/ DCF mode.

Fig 12 presents the delay variation for voice traffic using PCF/ DCF access modes. The figure shows declare difference in delay variation between the two methods which increase with simulation time. It is concluded that the real time traffic like voice must be operated in PCF mode to guarantee accepted delay variation and ETD delay. Fig 10 shows the received FTP traffic in a network using PCF and DCF access methods. The figure show there is small reduction in the received traffic using PCF (red line) compared with it by using DCF mode, this is due to FTP traffic in PCF mode haslow priority compared toDCF supported traffic. Fig. 11 shows average voice delay using PCF and HCF (EDCA), it shows that there is improvement by 4ms when using HCF access method. Also, Figure 12 shows that the best access method used for voice in WiFi network is HCF because it has the minimum delay variation. Fig 13 shows voice Mean Opinion Score (MOS) using PCF and HCF, it shows that HCF gives best MOS values compared with PCF.

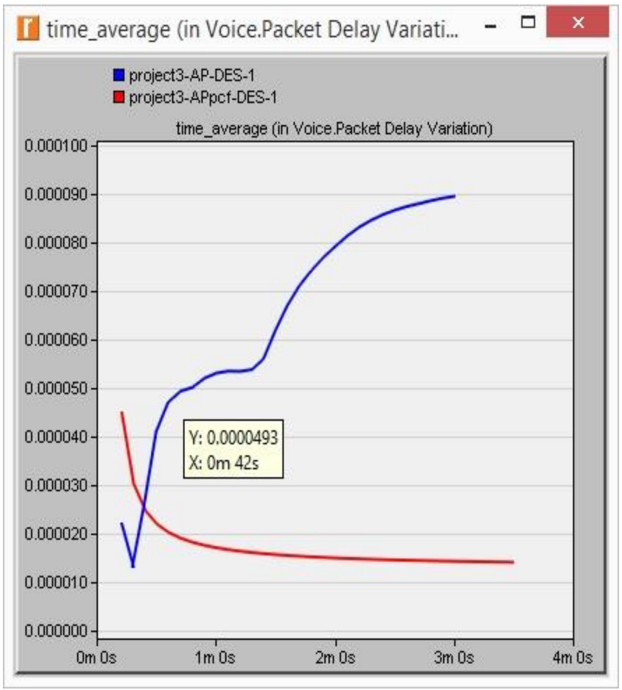

Figure 9. Voice delay variation in PCF/DCF

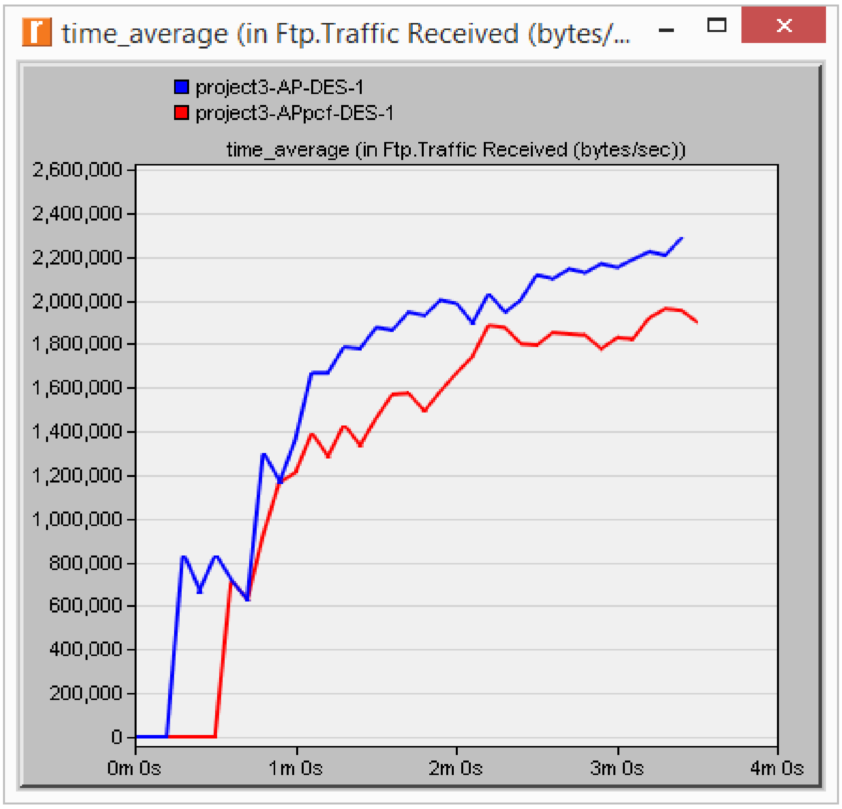

Figure 10. FTP received traffic using PCF/DCF

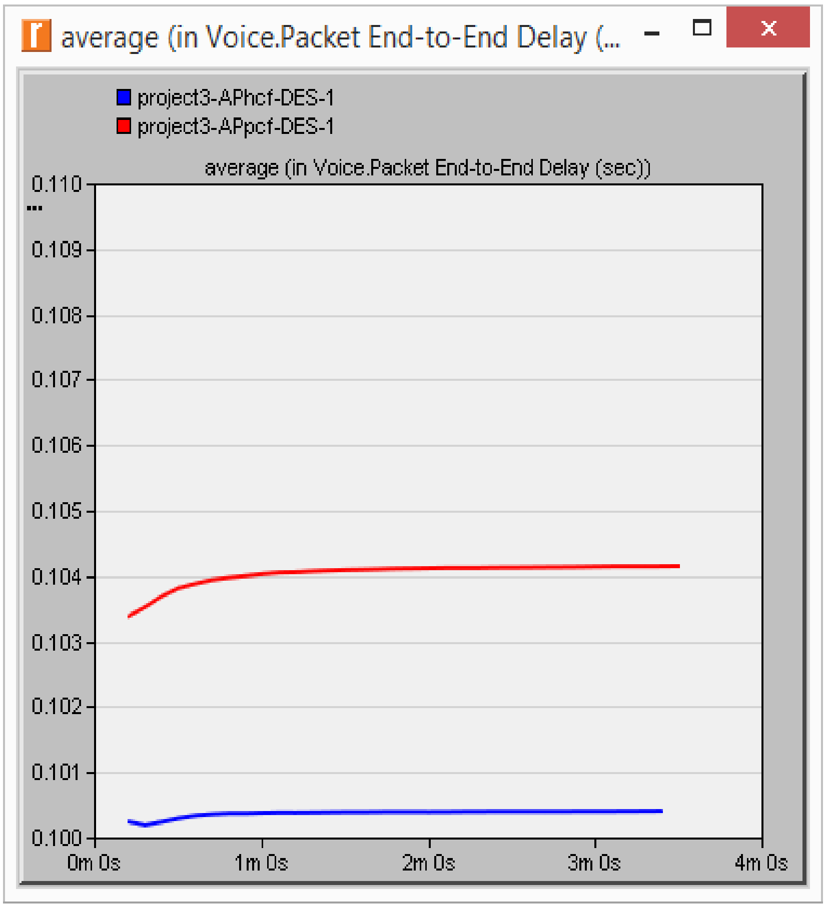

Figure 11. Average voice delay using PCF and HCF

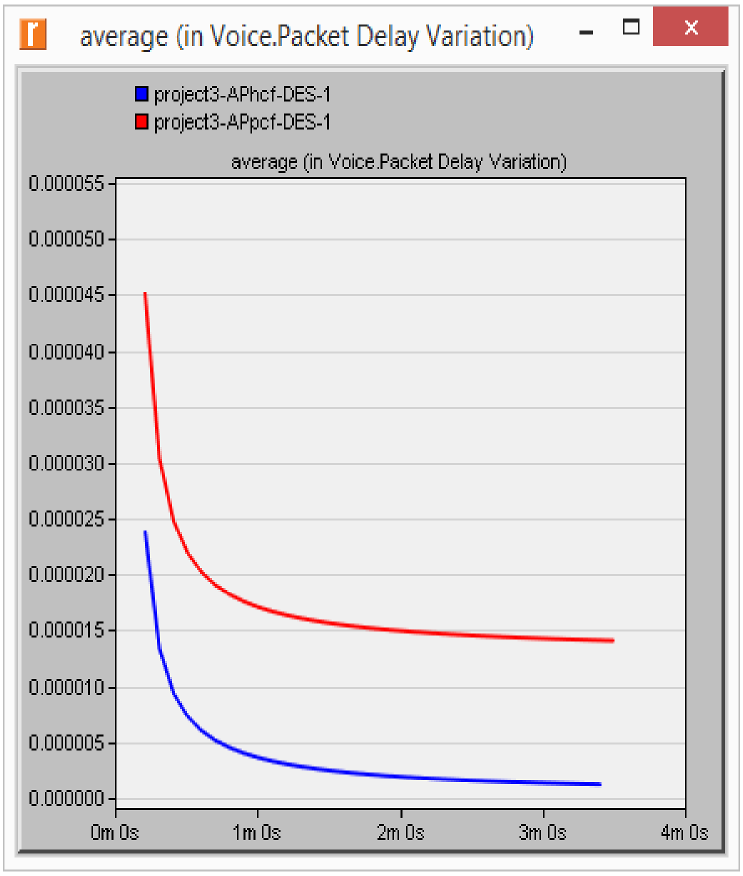

Figure 12. Average voice delay variation using PCF and HCF

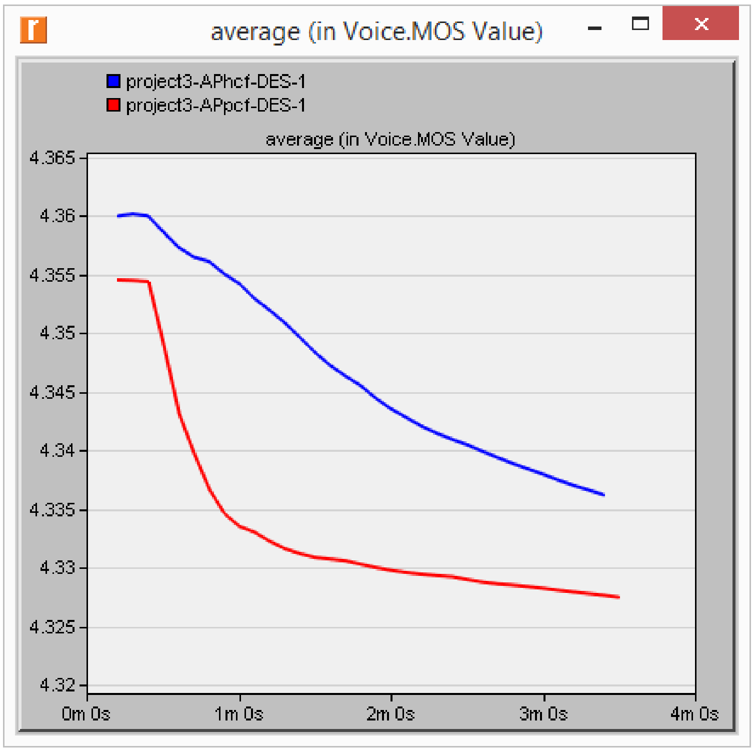

Figure 13. MOS using PCF and HCF

Fig.14 shows FTP received traffic using PCF and HCF, the results indicates that HCF makes slight improvements in FTP throughput.

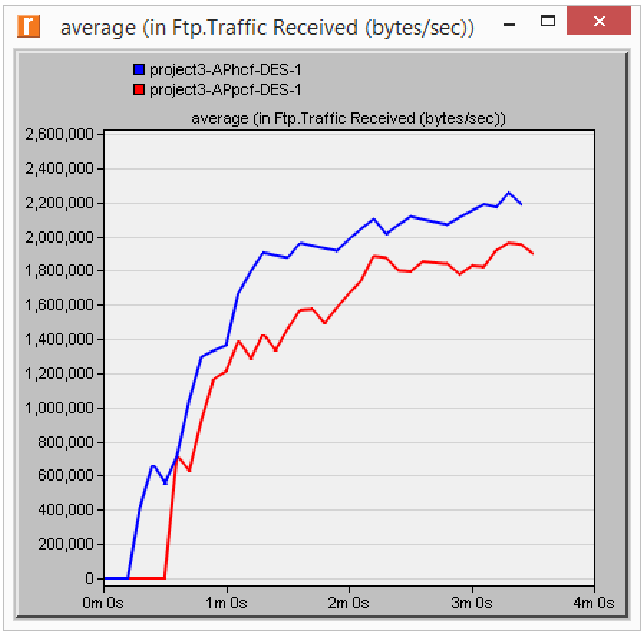

Figure 14. FTP received traffic using PCF and HCF

5. Conclusion

In WLAN there are many parameters which can affect the network performance. In this study fragmentation threshold, and RTS threshold are investigated to check it effect on network performance. Also changing MAC access technique has huge effect on the network performance. From the results it is clear that decreasing fragmentation threshold and RTS threshold increase the ETE delay of the traffic because of introduction of multiple SIFS intervals between fragments and RTS/CTS packets, respectively. But enabling these options increase the network reliability in noisy environments. The simulation shows that the best MAC access method for real time traffic lie voice is HCF, compared with DCF and PCF. If the network doesn't support HCF, voice must use PCF which improve MOS and decrease delay variation and ETE delay.

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