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Analyzing the Impact of DCF and PCF on WLAN Network Standards 802.11a, 802.11b and 802.11g

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***Abstract*—**Networking solutions, particularly wireless local area networks have revolutionized the technological advancement. Wireless Local Area Networks (WLANs) have gained a lot of popularity as they provide location-independent network access between computing devices. There are a number of access methods used in Wireless Networks among which DCF and PCF are the fundamental access methods. This paper emphasizes on the impact of DCF and PCF access mechanisms on the performance of the IEEE 802.11a, 802.11b and 802.11g standards. On the basis of various parameters viz. throughput, delay, load etc performance is evaluated between these three standards using above mentioned access mechanisms. Analysis revealed a superior throughput performance with low delays for 802.11g standard as compared to 802.11 a/b standard using both DCF and PCF access methods.

***Keywords*—**DCF, IEEE, PCF, WLAN.

I. Introduction

IEEE 802.11 made a great revolution over the past decade. Most of the wireless applications and cellular devices have expanded rapidly with advancement in the technology moving from small deployments that span the campus, offices to large enterprises and public sectors with its characteristics like cost-effective, mobility, flexibility etc. IEEE 802.11 consists of Physical Layer (PHY) and Medium Access Control (MAC) layer [1] that provides access between various location independent computing devices. The various popular 802.11 standards are 802.11a, 802.11b, 802.11g and 802.11n that define rules for communication over wireless local area networks. These standards support different data rate and modulation schemes. IEEE 802.11 original specification supports maximal data rate of 1 and 2 Mb/s. Further amendment in 802.11 was 802.11a and 802.11b finalized in 1999. IEEE 802.11a [2] uses 5 GHz frequency band and supports 54 Mbps of data rates where 802.11b standard supports a data transfer rate of 11 Mbps. A third PHY specification 802.11g was introduced in 2003 with maximum data rate 54 Mbps but with different frequency band 2.4 GHz. Further amendment is 802.11n improved over the previous WLAN standards with addition of multiple input and multiple output antennas (MIMO). It operates on both the 2.4 GHz and the lesser used 5GHz bands. A comparison between all these shown in table:

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TABLE I
Comparison of 802.11a, b, g and n Standards

802.11 protocol	Freq. (GHz)	Data rate Mbps	Modulation
a	5	6,9,18,12, 24,36,48,54	OFDM
b	2.4	5.5, 11	DSSS
g	2.4	6,9,18,12, 24,36,48,54	OFDM, DSSS
n	2.4/5	7.2,14.4,28.9, 57.8,65,72	OFDM

Our simulation study consist of 802.11 a, b and g protocols. This paper aims to outline the deployment of three popular WLAN standards i.e. 802.11a, 802.11b and 802.11g in wireless network and analyze the impact of DCF and PCF access mechanisms on these standards in OPNET simulator. The rest of the paper is organized is as follows. In Section II, we give some general insights of DCF and PCF protocols. In Section III background study is shown. Simulation test bed is done in Section IV. In Section V, we evaluate the performance results obtained from the OPNET simulations.

II. IEEE 802.11 WLAN

The IEEE 802.11 provides wireless communication to various computerized stations that require rapid deployment. Two fundamental access mechanisms that MAC sublayer supports are Distributed coordination function (DCF) and Point coordination function (PCF) [3].

A. Overview of DCF Access Method

Distributed Coordination Function is basic MAC protocol that utilizes Listen before talk and carrier sense multiple access with collision avoidance approach (CSMA/CA) [4]. A network using DCF protocol always senses the medium before transmitting any data. Before sending any data station executes Clear Channel Assessment (CCA) and listens to the channel for a DCF Inter Frame Space (DIFS) [5]. The station initiates the transmission as soon as it finds the channel is free in this DIFS period, otherwise the station executes a Binary Exponential Backoff Algorithm [6] by which if transmission failed or collision occurs, the station then sets a backoff counter at some random value within a predefined contention window called Backoff time As the medium is idle the counter is decremented. Each time the station finds the medium is idle; it waits for DIFS and continuously decrements the backoff timer by one unit. A new transmission occurs whenever this counter expires. A station has to wait before transmission and contention window at each station tells about the number of slot times it waits. As the data arrived successfully at destination an acknowledgement packet is send after Short Inter Frame Space (SIFS). This ACK packet notify sender that transmitted data frames have successfully received. However, if the sender doesn't receive any acknowledgement form receiver then it assumes that the frame was lost and schedules retransmission and starts the Backoff process again. After each successful transmission the contention window is reset to a fixed minimum value. During the channel busy period stations deferred from channel access continue to countdown the time of the deferred backoff instead of selecting new random backoff time after sensing the channel as being idle again. In this way deferred stations from channel access are given higher priority as their random backoff time is greater than the other stations. After each successful transmission, backoff process is performed again by station even if there is no MSDU. Now here backoff process is done after transmission and that's why this process is called "post backoff".

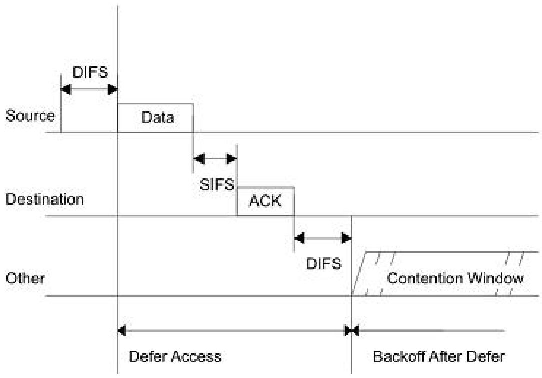

Fig. 1 DCF Access Method

B. Overview of PCF Access Method

Point Coordination Function (PCF) is a Media Access Control (MAC) technique that runs on infrastructure-based networks. In PCF access method all the stations access media through single Access Point (AP) that acts as Point Coordinator (PC) [4]. The PC uses polling scheme to determine which station can initiate data transmission. Stations in the network can optionally participate in PCF and respond to poll received from PC. Such stations are called CF-Pollable stations. In PCF enabled BSS the channel access time is divided into beacon intervals, a Contention Free Period (CFP) followed by a Contention Period (CP). In this access mechanism Point Coordinator (PC) hold list of all registered stations to be polled. Stations can transmit data or can receive data from AP only when they are polled. Because each station can transmit in a predetermine order, there is a bounded latency. Also the maximum CFP duration for all stations in network can be known and decided by PC called CFP_MAX_duration. AP initiates and maintains CFP which periodically transmits a Beacon (B). These beacons contain information about the duration of CFP and CP. The first beacon is transmitted after a CP is transmitted after a PCF Inter Frame Space. When AP sends a CF End control packet (CE), CFP is terminated.

The only station allowed to transmit is the one polled by AP during CFP. A station that is polled can transmit data to either AP or any other station in the network. If polled station doesn't have any data, it responds with a NULL packet.

As shown in Fig. 2 beacon is transmitted by AP to initiate CFP [5]. A poll packet and data both are combined to station 1 after SIFS. As station 1 receive this packet it acknowledges the reception of data packet and respond to the poll by transmitting a data packet to the AP. Now, AP combines a poll packet and data packet to station 2 after it acknowledges data packet received from station 1. Now station 2 acknowledges the packet to AP and transmits data to station 1 and after transmission of CE packet CFP is finished. Also after station 1 received the packet it acknowledged it and CFP ends with transmission of CE packet.

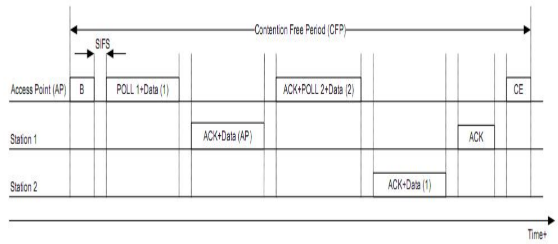

Fig. 2 PCF Access Method

C. DPCF Access Method

An extension of PCF is Distributed Point Coordination Function (DPCF) that allows the communication between computing devices in infrastructure less network. In this method stations can be operated in three different modes i.e. idle, master and slave [5]. The stations are idle in the initially stage. But whenever required the stations must be able to switch to two other modes i.e. slave and idle. The stations which are in the idle state having data to transmit get access to the channel executing the DCF. Whenever it gets access to the channel, it transmits a RTS packet targeted to the intended destination of the data packet. When the RTS packet is received at the destination, the destination of the packet becomes master and responds to the RTS with a beacon (B). On receiving a beacon (B), a PCF procedure is initiated and a spontaneous cluster is established. The stations which are in the idle state in the transmission range of the master become slaves and gets synchronized with the beacon. The first poll of the master, the one which transmitted the RTS is targeted to the station, having data to transmit. The master polls the slave following any arbitrary order for the duration of the cluster. The master maintains a counter which is incremented when each null packet is received upon polling. The counter is reset to zero when the station responds to poll with the transmission of data packet. But, if the counter gets to a maximum value, the master goes back to its idle mode after transmitting CE packets. On the other hand, any master has a Master Time Out (MTO) counter which determines the maximum duration of a cluster. E.g. the value of MTO=2 indicate that master station has transmitted 2 beacons and it is decremented by 1 after master station has transmitted 1 beacon. However, interbeacon time increases if ACK of received packet is combined with poll and data packet, station acknowledges the reception of data packet from master or third station transmits the ACK of

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the data packet received from second station. All the slave stations go into idle mode and perform random backoff period process after they receive CE packet.

III. Simulation Study

Our objective is to evaluate the performance of WLAN standards 802.11a, 802.11b and 802.11g on the basis of DCF and PCF access mechanisms in terms of throughput, end-to-end delays, retransmission attempts and load. The simulation set up is modeled in OPNET. The WLAN network consists of fixed WLAN stations. The simulation area is limited to the square area e.g. (100 * 100 m). Different networks have been simulated in two scenarios:-

a) In first scenario all stations only execute the IEEE 802.11 DCF with CSMA/CA mechanism in three different WLAN standard networks.
b) In second scenario a Point Coordinator (AP) manage the various stations access to the channel and execute the IEEE 802.11 PCF mechanism in three different WLAN standard networks.

Firstly, the WLAN network consists of nodes n=10 with transmission power tr = 0.005 w and data rate 12Mbps. The WLAN standard used is 802.11a with OFDM and MAC sublayer access mechanism used is DCF. Similarly, two other networks are deployed by duplicating the same scenario but with different WLAN standards i.e. 802.11b and 802.11g. Another scenario is created using WLAN standard 802.11a with same number of nodes and transmission power but now access mechanism used is Point Coordination Function (PCF) using DCF. Again two more networks are deployed by duplicating this scenario and each network use a different WLAN standard e.g. 802.11b and 802.11g. The parameters that are calculated are network throughput, delay, and load and retransmission attempts. Also, the performance of WLAN network is calculated by comparing both DCF and PCF mechanisms using WLAN standard 802.11g with node density n=10 and transmission power tr = 0.005w. The buffer size is set to 5708000 and various traffic parameters are also set.

IV. Simulation Results

This section discusses simulation results performed on WLAN network standards 802.11a, 802.11b and 802.11g.

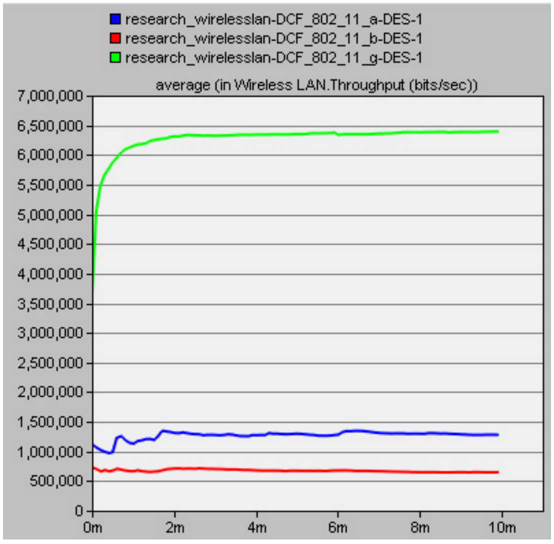

Fig. 3 Throughput of WLAN 802.11a, b and g using DCF

Throughput defines the total number of bits forwarded from wireless LAN layers to higher layers in all WLAN nodes in the network. From Fig. 3, the throughput of WLAN 802.11a, b and g standards is shown with DCF as access mechanism. The node density is n = 9 and transmit power (w) is 0.005. It is clearly observe that WLAN standard 802.11g achieves highest throughput i.e. 6,500,000 bits/sec compared to 802.11b and 802.11g. Where WLAN network using standard 802.11b has lowest throughput i.e. 6, 00,000 bits/sec, WLAN 802.11a has throughput 1,400,000 bits/sec. approx.

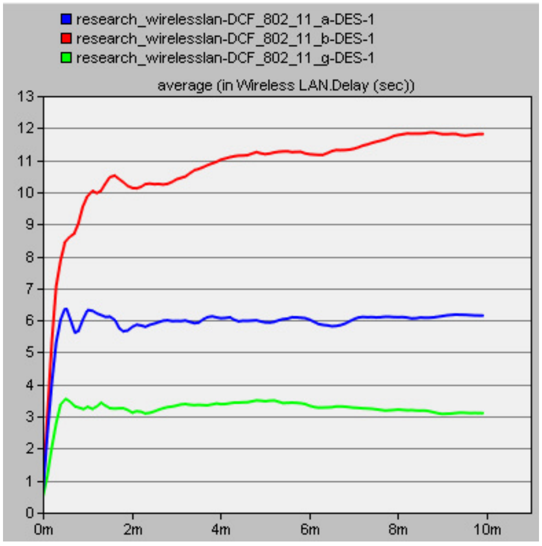

Fig. 4 End-to-End Delay of WLAN 802.11a, b and g using DCF

Delay is represented as end to end delay of all the data in packets received by WLAN MAC layer of all the nodes in the network. It includes medium access delay, reception of fragments individually etc. From Fig. 4 graph 802.11g delay is very less and constant i.e. 3 sec. compared to WLAN 802.11a and b. WLAN 802.11a achieves higher delay of 6 sec. and there is a sharp increase in the delay of WLAN 802.11b.

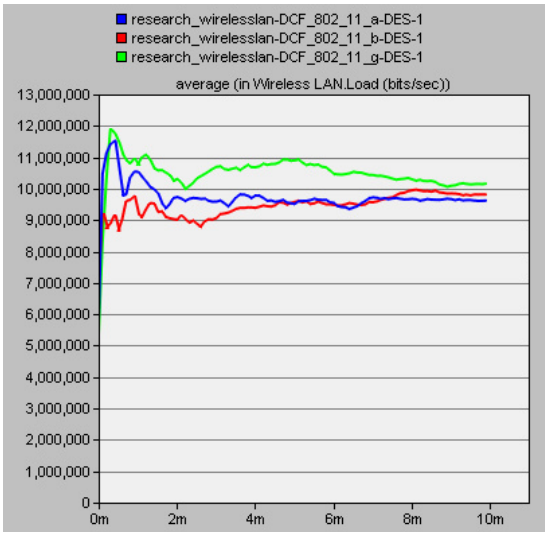

Fig. 5 Load of WLAN 802.11a, b and g using DCF

Load is defined as the total load in (bits/sec) that Wireless LAN layers receive from all higher layers of WLAN nodes in network and doesn't include the higher layers packet bits dropped by WLAN MACs. From Fig. 5 we can easily observe that load is almost same for WLAN 802.11a and b standards i.e. 9,500,000 bits/sec. where as it is slightly higher than in case of 802.11g 10,500,000 bits/sec.

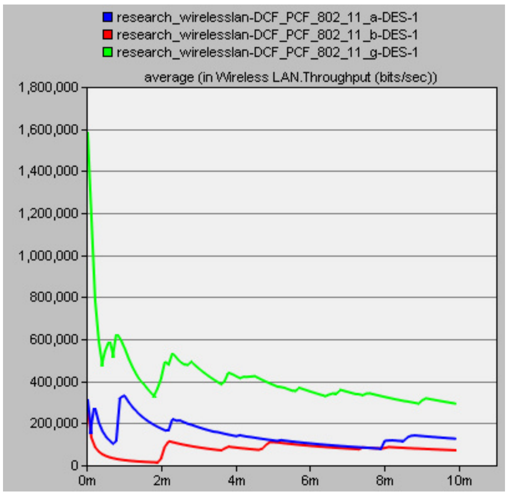

Fig. 6 Throughput of WLAN 802.11a, b and g using PCF

Now WLAN network standards use DCF access mechanism using PCF. Even though PCF access method uses real time traffic but still it has disadvantage that it cannot guarantee QoS. Another disadvantage of PCF method is wastage of bandwidth. DPCF access mechanism is used in infrastructure less networks. The stations behave in three different modes idle, master and slave. Any time a station can switch in other two modes i.e. idle or slave.

It is clearly visible from Fig. 6, that throughput is same in both WLAN network standards 802.11a and b 50,000 bits/sec and higher in WLAN 802.11g. However, at first throughput of WLAN 802.11g was near about 1,800,000 bits/sec than there is a sudden decline in the throughput and become constant at 400,000 bits/sec approx.

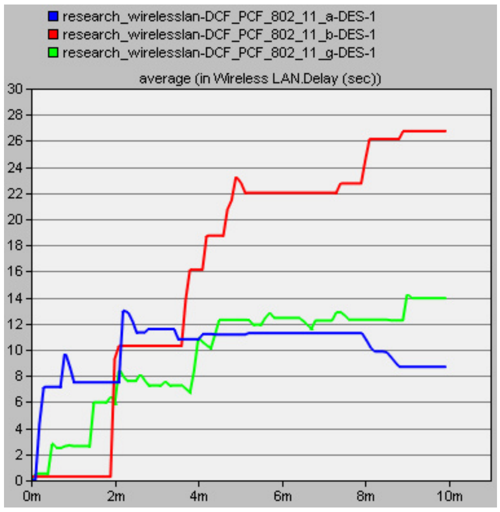

Fig. 7 End-to-End Delay of WLAN 802.11a, b and g using DCF_PCF

From Fig. 7 we can clearly see that in the beginning delay is almost negligible and after that it is drastically increasing and rose to 26 seconds in WLAN 802.11b, whereas in WLAN 802.11a it rose to 12 seconds and then become constant and there is a slight increase in end to end delay in WLAN 802.11b comparing to 802.11a i.e.14 seconds.

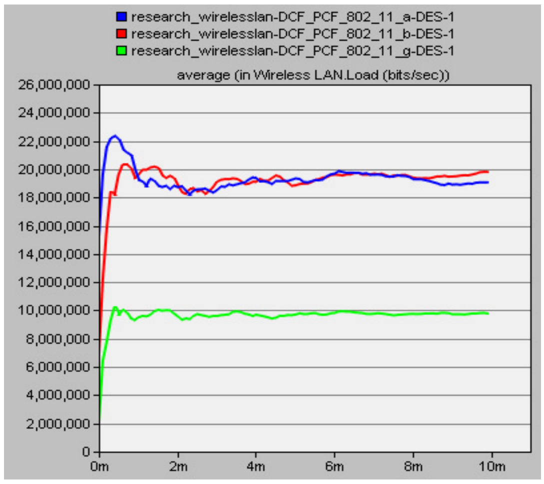

Fig. 8 Load Delay of WLAN 802.11a, b and g using DCF_PCF

Fig. 8 shows load of WLAN 802.11a, b and g standards. It can be observe from the graph that load is almost same for WLAN 802.11a and b network standards which is 19,000,000 bits/sec. where as it is quite low in wireless network using 802.11g standard i.e. 10,000,000.

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A. Comparison of WLAN Using DCF vs. WLAN Using DCF_PCF

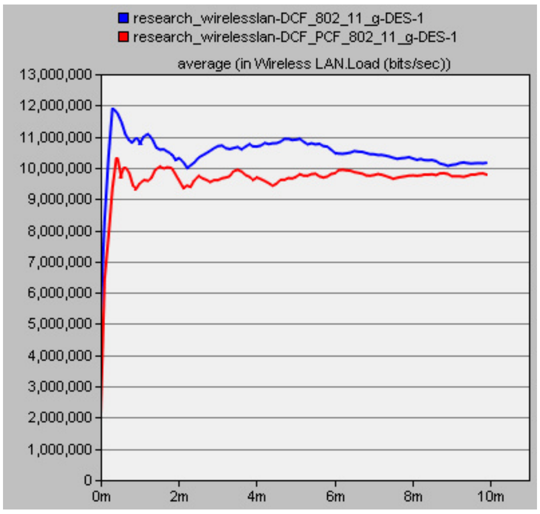

Fig. 9 DCF vs. DCF_PCF load

For comparison between WLAN access mechanisms DCF and DCF_PCF we have choose wireless standard 802.11g. Fig. 9 depicts the load is total load submitted by al WLAN layers nodes in the network to the upper higher layers and doesn't include the packets that are dropped by higher layers. It is clear that load of PCF enabled WLAN 802.11g is lower than wireless network using DCF mechanism only which is 10,000,000 bits/sec. The reason behind it is when PCF is disabled then the packets received from higher layers needed to be buffered and some of them load the buffer space and resulting into dropping of packets. So, when PCF is enabled the dropped packets are not included.

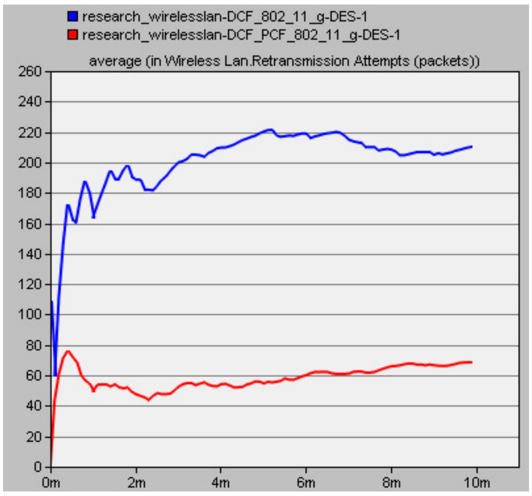

Fig. 10 DCF vs. DCF_PCF Retransmission Attempts

Retransmission attempts occurred in network when packets are lost or damage during transmission. Fig. 10 shows retransmission attempts of WLAN 802.11 network standard with PCF shown in red line and without using PCF access mechanism shown in blue line. Fig. 10 clearly shows retransmission attempts are less in wireless network when PCF is enabled i.e. 60 packets, it is because PCF reduces the number of collisions by taking advantage of contention free periods and hence reduces retransmissions where WLAN using only DCF mechanism, the number of retransmission attempts are more i.e. 220 packets approximately.

V. Conclusion

In this paper, we analyzed the impact of DCF and PCF access mechanisms on the performance of the IEEE 802.11a, 802.11b and 802.11g WLAN standards. We also evaluated performance of WLAN network using 802.11a, b and g standards in different scenarios on the basis of different parameters viz. throughput, end to end delay, load, retransmission attempts etc. The performance revealed that WLAN 802.11g standard outperformed and can be used for high bandwidth data with lower delays compared to 802.11a and b network standards when networks are using only DCF as access mechanism. However, different variations have been seen in end to end delay and throughput when network is enabled with PCF as access mechanism. At the end comparison is made between DCF vs. DCF_PCF using standard 802.11g and concluded that lower retransmission attempts and load is achieved when DCF is using PCF compared to WLAN network using only DCF.

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