

A Study on Delay, Throughput and Traffic Measurement for Wi-Fi Connected Stations Based on MAC Sublayer

Md. Abbas Ali Khan^{*1}, Khalid Been Md. Badruzzaman Biplob² and Md. Sadekur Rahman³

¹School of Technology and Health, KTH Royal Institute of Technology, Stockholm, Sweden

²Research Associate, Department of Software Engineering, Daffodil International University, Bangladesh

³Senior Lecturer, Department of Computer Science & Engineering, Daffodil International University, Bangladesh

Address for Correspondence

School of Technology and Health, KTH Royal Institute of Technology, Stockholm, Sweden
Tel.: 0088 01924 196 829

E-mail: dobila2005@gmail.com

ABSTRACT

Solutions of networking, especially in WLAN, where wire is not used to communicate and focusing technological advantages to offering place-independent networking among the short range wireless devices. The MAC sublayer of IEEE 802.11 stands for WLAN (Wireless Local Area Network) is mainly includes two fundamental access methods. One is called DCF (Distributed Coordination Function), which uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) approach. Other is PCF (Point Coordination Function), which is based on polling to determine the station that can transmit next. This paper is mainly focuses on the delay measurement, throughput, and traffic load of the network and also the impact factor of the DCF and PCF method of accessing to analyze more performance of throughput and less delay.

Keywords: DCF, Delay, MAC and PCF.

INTRODUCTION

IEEE 802.11 standard was the first standard describing the operation of wireless LANs. This standard contained all of the available transmission technologies including DSSS, FHSS and operating 2.4 GHz ISM (unlicensed) band at data rates of 1 Mbps and 2Mbps. IEEE 802.11a standard operates 5 GHz band, OFDM modulation technique with 54 Mbps data rate. IEEE 802.11b standard supports up to 11 Mbps and it uses the 2.4

GHz frequency with DSSS spreading technique. IEEE 802.11g standard has OFDM technique in the 2.4 GHz band with 54 Mbps data rate. There are 14 RF channels (13 in Europe and 1 in Japan) with 22 MHz bandwidth. The DS and BSSs allow IEEE 802.11 to make wireless network arbitrary size and complexity. ESS appears as a single logical LAN to the logical link control level (LLC). A portal is used to integrate IEEE

802.11 architecture with a traditional wired LAN. The MAC layer is subject to provide reliable data delivery, medium access control and security for IEEE 802.11 local area network (LAN). The IEEE 802.11 MAC layers uses physical layer such as 802.11b and 802.11a, the tasks to perform carrier sensing, transmitting and receiving 802.11 MAC frame⁶.

A wireless LAN is one that makes use of a wireless transmission medium, ad hoc-networking, and coverage of locations difficult to use wire. The MAC sub layer is mainly includes two fundamental access methods. One is called DCF (Distributed Coordination Function) which uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) approach¹. Other is PCF (Point Coordination Function) which is based on the polling to determine the station that can transmit next and provide contention-free services¹. The physical CSMA/CA, DCF and PCF utilize virtual carrier sense mechanism to determine the state of the medium. This is implemented with the help of Network Allocation Vector (NAV) which provides each station with a prediction of future traffic on the medium³. The standard also allows for fragmentation of the MAC data units into smaller frames, which is very favorable in case of wireless channel as it is not reliable enough to transmit longer frames. In this Paper a OPNET simulation is shown of a WLAN network with nine wireless stations named as node_0 up to node_8. Node_0 has its **Access Point** Functionality enabled and acting here as Point Coordinator¹. These stations are configured in four ways. Discussion is shown in below the DCF scenario, DCF_PCF scenario, DCF_Frag Scenario, DCF_PCF_Frag Scenario and then analysis their effect on delay, throughput and traffic load. Also it is shown how to get more throughputs and less delay in the network.

SCENARIO OF DCF & PCF

DCF Scenario

DCF is implemented in all stations in the wireless local area networks by default. With DCF, every station senses the medium before transmission, defer as long as the medium is busy and when medium goes idle, wait for a random backoff interval⁵. After backoff interval, if medium is still idle, the station initiates data transmission or optionally exchange RTS (Request to send)/CTS (Clear to send) frames¹.

DCF_PCF Scenario

PCF access method is implemented 'optionally' in an infrastructure network along with the DCF. With PCF, the access point (AP) in the network acts as a Point Coordinator (PC)⁴. The PC uses Polling based approached to determine which station can transmit data. It is optional for the stations to participate in the PCF. Those stations which respond to the poll received from the PC are called CF-Pollable stations. The PCF functionality has been enabled on node_0, node_1, node_3, node_5 and node_7.

DCF_Frag Scenario

This scenario has been duplicated from DCF scenario and here on all stations; Fragmentation Threshold size of 256 bytes has been set. So fragmentation of the frames will occur if their size exceeds the fragmentation threshold (which is of 256 bytes). Here in case of DCF and during contention period, all fragments of a single frame will be sent as burst with a single invocation of the DCF medium access procedure. (See fig. 1.1)

DCF_PCF_Frag Scenario

This scenario has been duplicated from DCF_Frag scenario due to which Fragmentation Threshold of 256 bytes has already been set on all stations. Then PCF functionality has been enabled on node_0,

node_1, node_3, node_5 and node_7. Here in case of PCF and during a contention free periods, fragments are sent individually following the rules of the PC. As discussed above, DCF is based on CSMA/CA and there is a contention for the medium among the stations. A station only senses the medium before transmission. If the medium is idle, it transmits otherwise if the medium is busy; a station that wishes to transmit has to wait until the current transmission is over and for an additional random back off interval. Thus in this way, there may have collisions which requires retransmission of data after receiving the negative ACKs from receiver^{1, 2} This additional traffic due to the retransmission causes the traffic load in the network. In case of PCF, the existence of AP and CF-Pollable stations creates the contention free period and each station transmits its required data only on its designated interval according to the poll issued by the AP. This causes the collision free transmission and there will be less requirement of retransmission. In the figure 1.1 shown, it has been observed clearly that DCF scenario without PCF (shown in Red and Blue colors) is suffering with higher loads as compared to DCF scenario with PCF (shown in Green and Sky blue colors). The possible cause of this high load is additional traffic of retransmissions, required due to possible collisions in case of DCF scenario. Let see the effect of utilizing PCF and Fragmentation on delay first.

SIMULATION RESULT

Effect of PCF on Delay

As discussed above, DCF is based on CSMA/CA in which station has to wait until the medium becomes idle and then additional wait for back off time before it can transmit anything. In addition to this, as PCF pollable traffic has more priority so it has to wait until the traffic of any CF-Pollable station becomes over. In addition to this, in DCF, station has to wait for additional SIFS (Shortest IFS)

before sending of data and another SIFS before getting an ACK from the receiver¹. While in case of PCF, station suffers on delay of its polling turn which depends on the number of Pollable stations. If number of pollable stations is higher, then delay for receiving a poll from the PC will be higher. But as here number of pollable stations is only five due to which polling delay is significantly very low.

Effect of Fragmentation on Delay

In fragmentation, the frames which are larger than 256 bytes¹ are fragmented into smaller frames. This will cause additional delay because at the transmission side, first large frame will be chopped down into smaller subframes, then each subframe will be added with its header. Similarly, at the receiver end, header will be removed from each subframe and then reassembled into a larger frame. In case of DCF, this delay can be seen significant because here each packet will have to wait before it can access the medium. Similarly, as the number of frames has been increased, the number of collisions may be increased too. This will cause more retransmissions resulting in more delays for the reassembly of the error free subframes into larger frame at the receiver side. The delay due to this fragmentation is relatively small in case of PCF enabled scenario. The effect of PCF and Fragmentation on Delay can be seen in the figure 1.2. As discussed above, DCF_Frag (shown with red line) has the highest delay followed by DCF (shown with blue line). DCF_PCF_Frag (shown with sky blue color) has fragmentation delay and the DCF_PCF (shown with Green color) has the smallest delay as compared to other scenarios.

Effect of PCF on Throughput

The scenario without PCF will suffer more delays and thus throughput is small as compared to the scenario with PCF. Secondly, because of the retransmissions due to any

possible collisions, effective throughput will also be relatively small as compared to scenario with PCF. Effect of Fragmentation on Throughput, refer to the discussion above, in case of DCF only, the number of frames will be increased, which will cause more collisions resulting in greater number of retransmissions. This will cause effective throughput to be decreased as compared to the throughput in case of scenario with PCF. The above two findings can be seen clearly in the figure 1.3. The highest throughput is in DCF_PCF (shown with Green color) followed by DCF_PCF_Frag (shown with sky blue color). The low throughput is in DCF (shown with Blue color) followed by the DCF_Frag (shown with red color) showing the lowest throughput among the four scenarios. Referred to the figure 1.4 and figure 1.5, in DCF_PCF scenario, node_2 has its PCF Functionality disabled while node_3 has its PCF functionality enabled. Figure 1.4 shows the delay in node_2 and node_3 while figure 1.5 shows the retransmission attempts in node_2 and node_3. As seen in figure 1.4, node_2 and node_3 has almost the same results for DCF and DCF_Frag scenarios. But in case of DCF_PCF and DCF_PCF_Frag, the delay is much higher in node_2 as compared to that in node_3. The reason for this is that in case of PCF enabled in some nodes, the CF-pollable nodes (like node_3) can transmit right away without any delay in the collision free period (CFP) and the non-CF-Pollable nodes (like node_2) experience higher delays due to the existence of the collision-free period during which only CF-Pollable nodes are permitted to transmit. In the figure 1.5, the number of retransmissions in node_3 is considerably low as compared to that in node_2 for the four scenarios. The reason for this is that, in node 3, when PCF is used, it guarantees that there will be no collision as each station is transmitting at its desired interval and thus there will be no retransmission. So the number of transmissions will be lower for DCF_PCF

(shown with green color) and DCF_PCF_Frag (shown with sky blue color) in node_3 as compared to node_2. Secondly, the nodes with PCF enabled do not compete for access to the medium, so there will be lower number of stations (nodes) that will contend and transmit during contention period. Thus the number of retransmissions for DCF_Frag (shown with red color) and DCF (shown with blue color) will also be relatively smaller in node_3 as compared to those in node_2. Referred to the figure 1.6 and 1.7 are actually doing comparison between the two scenarios where in one scenario, have only two PCF enabled nodes (called DCF_two PCF) and the other scenario when have PCF enabled on all nodes (called DCF_allPCF). Referred to the Figure 1.6 is shown the comparison of delay statistics for DCF_twoPCF and DCF_allPCF.

It can be seen that the delay in DCF_twoPCF (shown with Pink color) is much higher as compared to the delay in case of DCF_allPCF (shown with Yellow color). As discussed above, the reason for it is that have much chance of collisions and the respective retransmissions when have only two PCF enabled nodes, causing much delay. But when we have all PCF enabled nodes, then there are almost no collisions and retransmissions resulting in much less delay. For the same reason, in Figure 1.6 (a) throughput in DCF_allPCF (shown with Yellow color) is much higher as compared to that DCF_twoPCF (pink color).

According to the Figure 1.7 shown, is getting unusual result of load comparison between DCF_allPCF and DCF_twoPCF, because usually if it has less delay and more throughputs, so expect fewer loads in the network. But here DCF_allPCF have more loads (shown with Yellow color) as compared to that in case of DCF_twoPCF (shown with pink color). The possible reason for it can be that, in case of DCF_allPCF, the number of Polls sent by the PC is higher due to the greater number of CF-Pollable nodes as

compared to the number of polls sent when only two CF-Pollable nodes have in DCF_twoPCF scenario. This can cause extra load in the network even if there are not any collisions and the resulting retransmissions. If the number of CF-Pollable nodes in the network is increased, this load effect can be experienced more significantly in that case. The Medium Access Delay for all six scenarios is shown in Figures 1.8 and 1.9. From the Figure 1.8, it can be seen clearly that DCF_Frag (shown with Green color) has the highest medium access delay followed by the DCF (shown with Red color) as compared to remaining PCF enabled scenarios. As discussed in above, the reason for high delay in DCF scenarios (DCF_Frag and DCF) is that there is no PCF enabled nodes and all the nodes are accessing the medium during the contention period resulting in collisions and corresponding retransmissions. Between DCF_Frag and DCF, DCF_Frag has more delay because of the fragmentation issues as discussed above. For the remaining four PCF enabled scenarios, results are seen unexpected in Figure 1.8 so their simulation results have been generated again and shown in Figure 1.9. As per Figure 1.9 shown, it can be seen clearly that DCF_PCF_Frag (shown with sky blue color) has higher medium access delay as compared to the remaining DCF_twoPCF, DCF_PCF and DCF_allPCF scenarios. The reason for this is the same fragmentation issues as discussed in above. For the remaining three scenarios, DCF_twoPCF (shown with pink color) has more delay compared to DCF_PCF and DCF_allPCF. The reason for it is the effect on delay due the number of CF-Pollable nodes in the network discussed in above. In DCF_twoPCF, there are only two CF-Pollable nodes resulting in higher number of nodes to work in Contention period resulting in more collisions and corresponding retransmissions. In DCF_PCF (shown with green color), almost half of all the nodes are CF-Pollable resulting in half of the nodes in the network to work

during Contention Free period resulting in significantly less number of collisions and retransmissions. Finally in DCF_allPCF (shown with Yellow color), the medium access delay is the lowest as almost all the nodes are working in Contention Free period and there are not any significant collisions and retransmissions.

CONCLUSION

The DCF_Frag has the highest delay followed by DCF when PCF is not enabled on all the nodes in the network. When PCF is enabled in the network, DCF_PCF_Frag has higher delay followed by DCF_twoPCF, DCF_PCF and DCF_allPCF respectively. Polling delay is happened if the number of pollable station is more. To make less such delay uses less number of polling stations. And traffic load occurs due to retransmission. Less number of collisions and retransmissions are occurred during the contention free period. If it is being ensured less traffic load (retransmission) in the network then potentiality is more to get less delay and more throughputs.

REFERENCES

1. Stallings William, *Wireless Communication & Networks*. 2nd edition, P-435-445, prentice-Hall of India, New Delhi-110 0001
2. Larry L. Peterson & Bruce S. Davie, *Computer Networks: A System Approach*, 4th edition, section 2.8.2, P-140
3. <http://www.vocal.com/networking/802-11-distributed-coordination-function-dcf/>
4. Sarah Shaaban, Dr. Hesham M. El Badawy, Prof. Dr. Attallah Hashad, "Performance Evaluation of the IEEE 802.11 Wireless LAN Standards," *Proceedings of World Congress on Engineering*, vol. I, 2-4, 2008.
5. Moustafa A. Youssef, Arunchand ar Vasan, Raymond E. Miller "Specification and analysis of the DCF and PCF protocols in the 802.11 standard using systems of communicating machines", 2002, ISSN:1092-1648,pp:132 –141.

- 6. Anonymous, “The 802.11 protocol stack and physical layer” [http://www.scribd.com/doc/13628928/80211-Protocol-Stack-and-](http://www.scribd.com/doc/13628928/80211-Protocol-Stack-and-physical-Layer)

physical Layer, Accessed November 12, 2010.

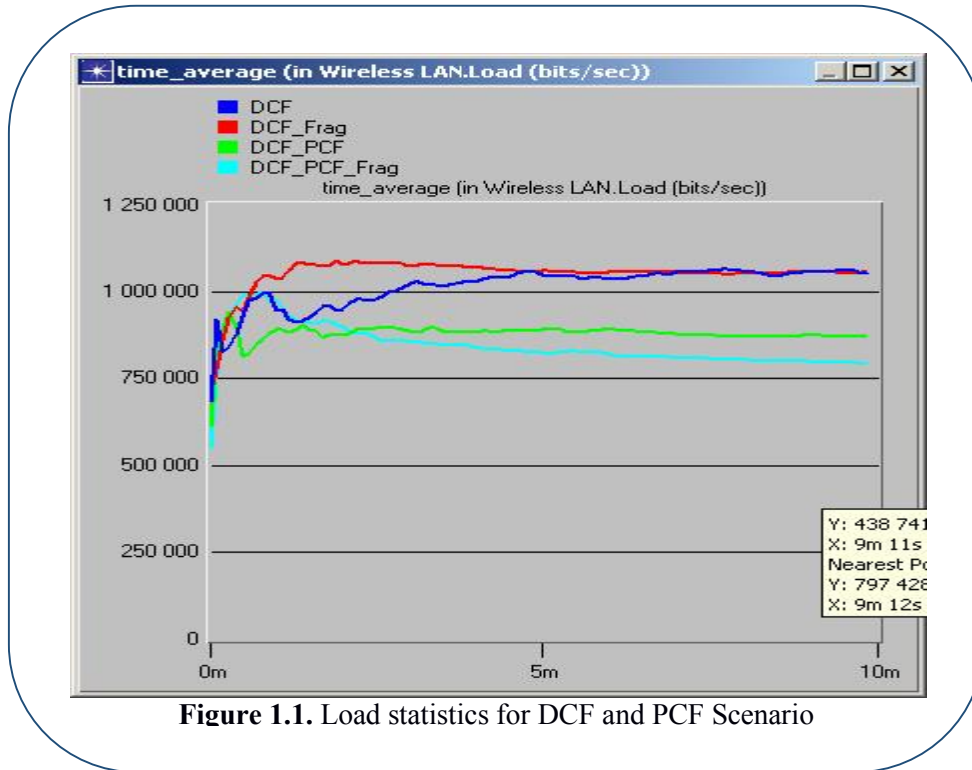


Figure 1.1. Load statistics for DCF and PCF Scenario

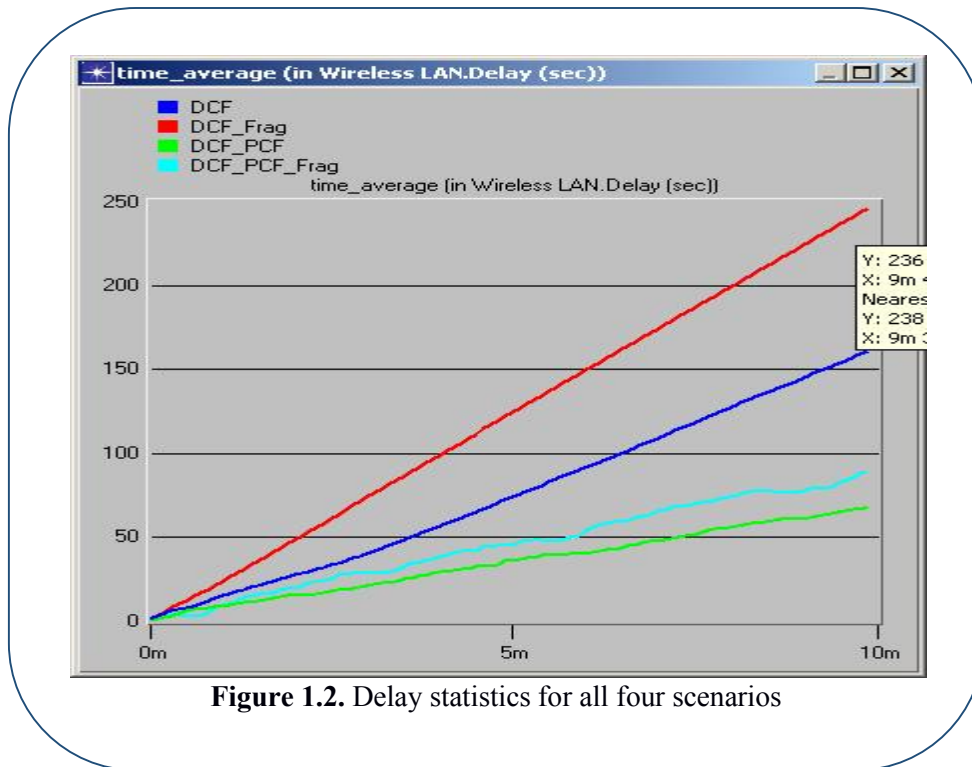


Figure 1.2. Delay statistics for all four scenarios

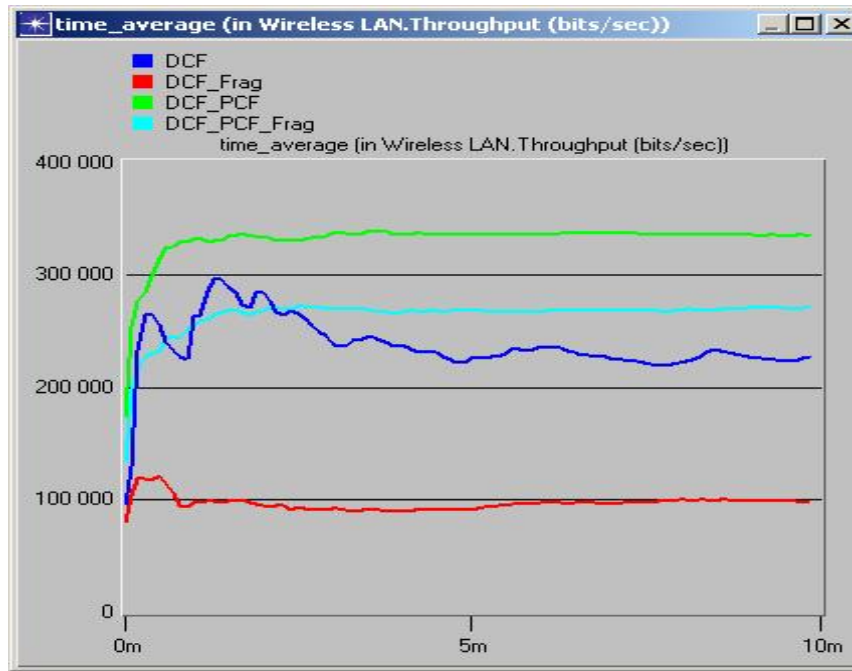


Figure 1.3. Throughput statistics for all four scenarios

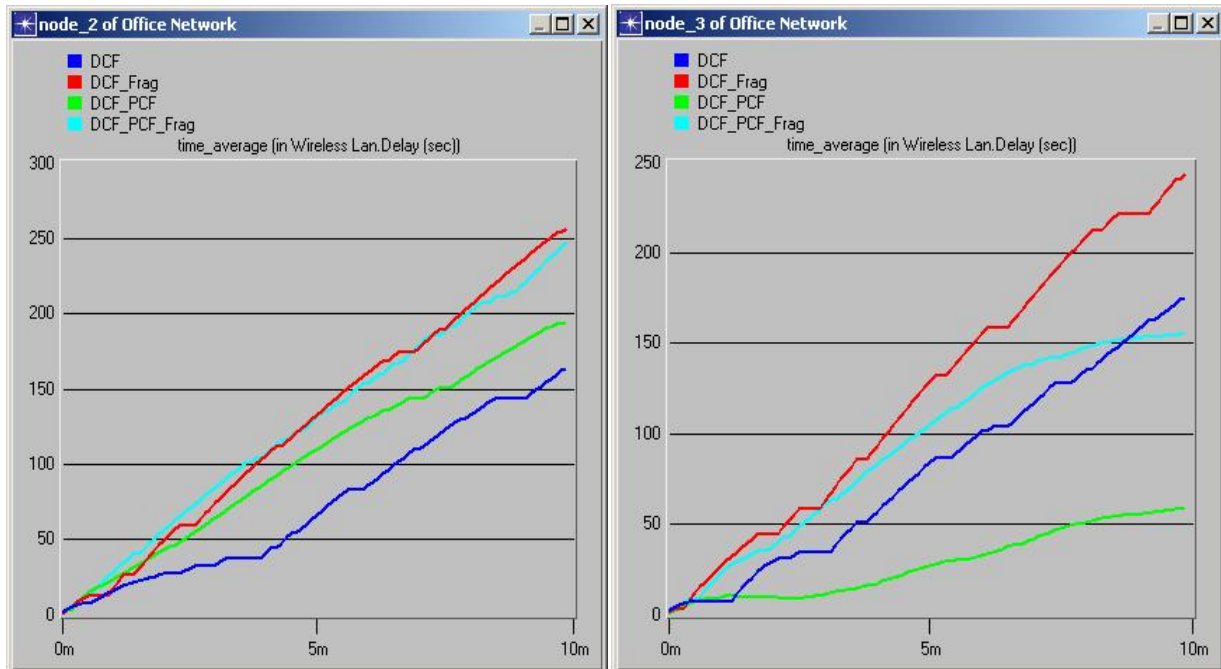


Figure 1.4. Delay Station for node_2 and node_3 (in DCF_PCF scenario)

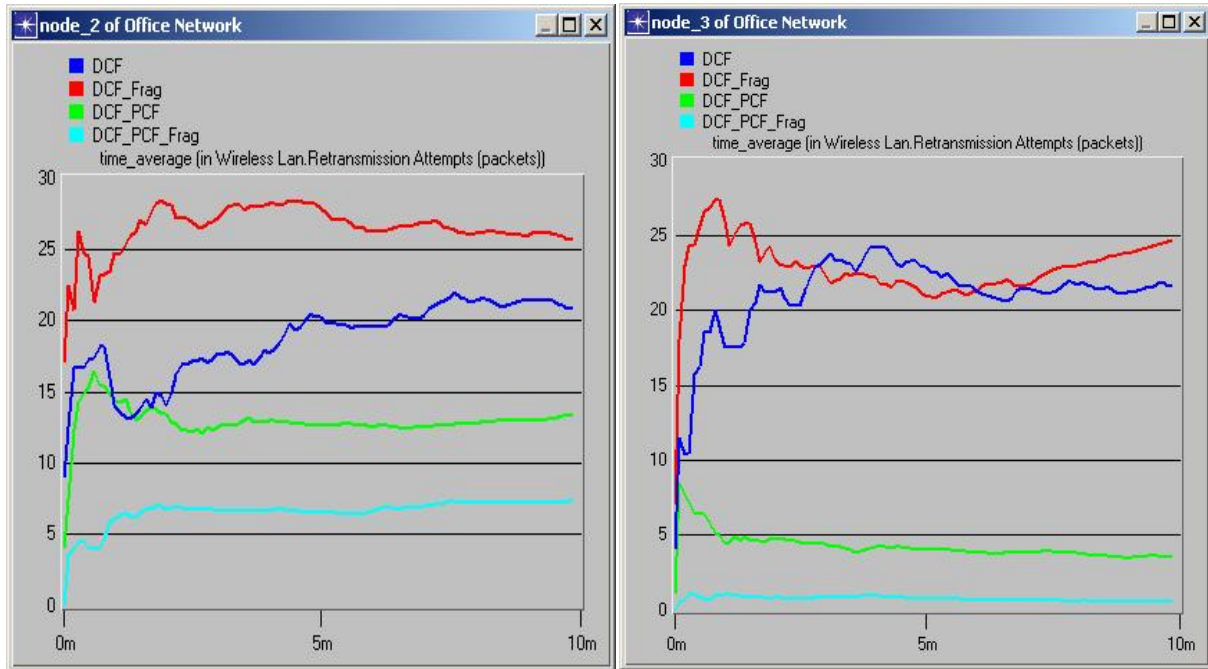


Figure 1.5. Retransmission Attempts statistics for node2 and node 3 (in DCF_PCF scenario)

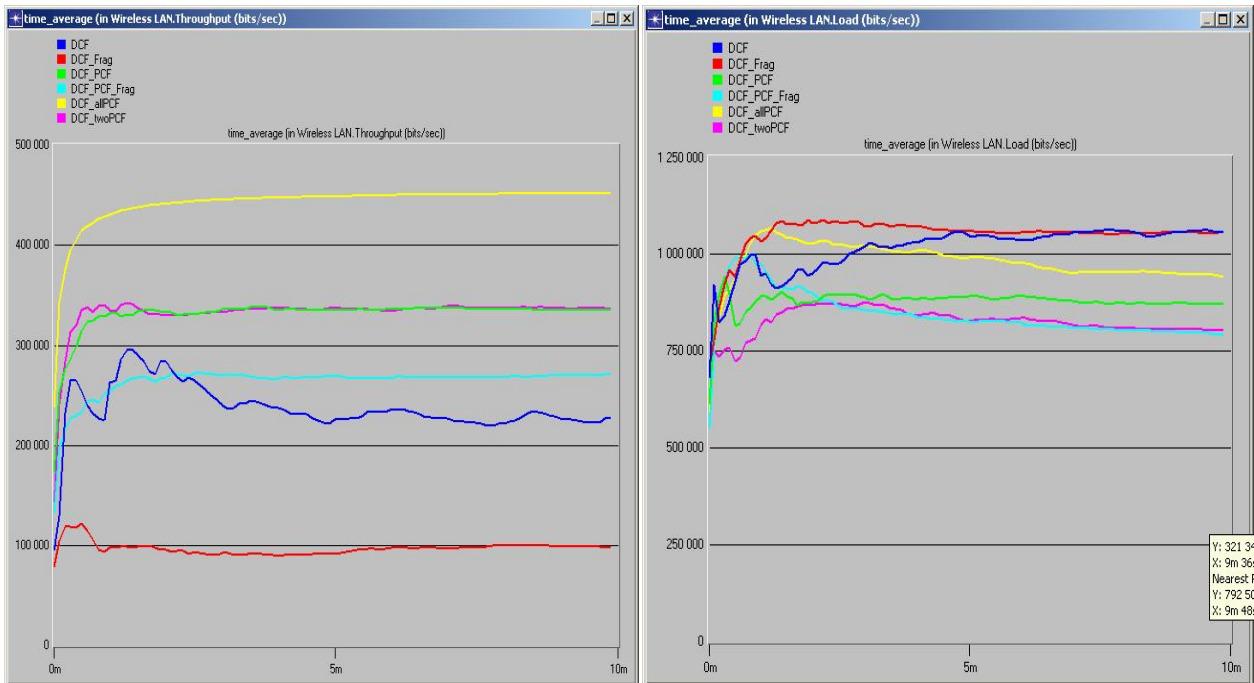


Figure 1.6(b) Delay and Throughput Figure 1.6 (a) statistics for DCF compared to that in DCF_twoPCF (shown with Pink color).allPCF and DCF_twoPCF

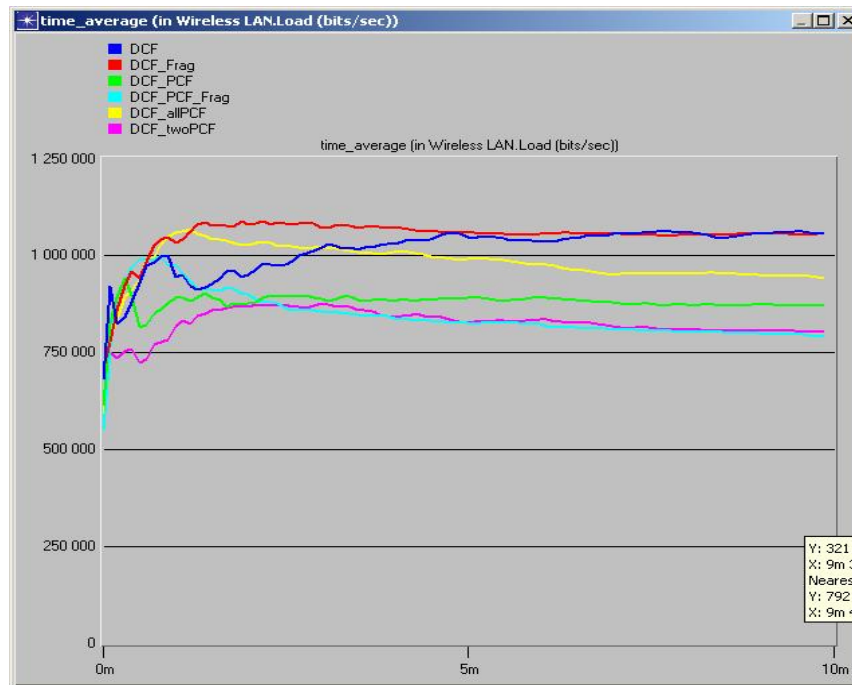


Figure 1.7. Load statistics for DCF allPCF and DCF twoPCF

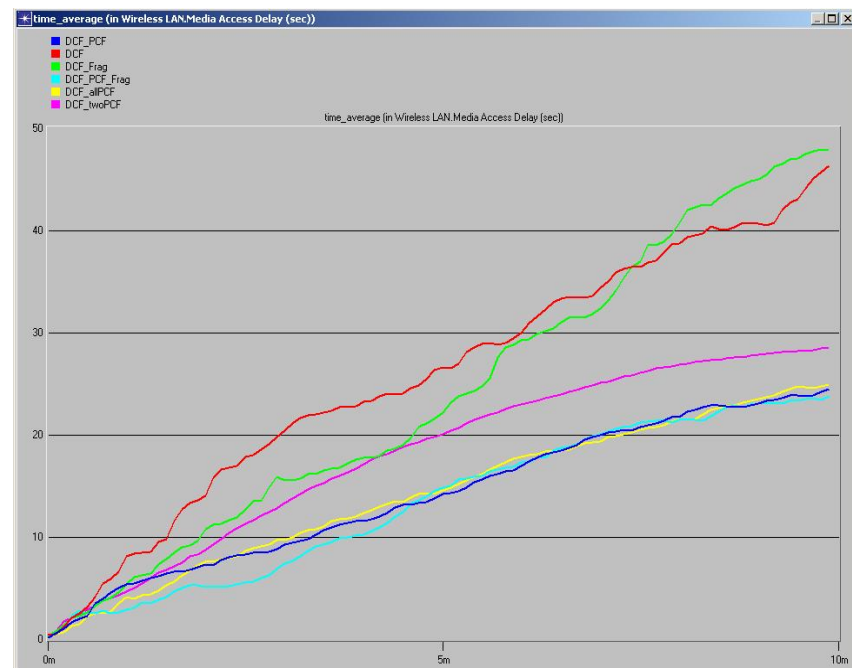


Figure 1.8. Medium Access Delay statistics for DCF_Frag and DCF.

