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Modeling and Analysis of WLANs Throughput considering Aggregation with capture effect scheme using MATLAB

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***Abstract*— Wireless local area network (WLAN) allows access to wider internet by interconnecting two or more devices with or without access point using wireless distribution method. Since the basic requirement of the Wireless LAN is to achieve higher throughput many suggestions and investigations are involved in this area and lot of enhancement are taking place in this field. Many researchers actively contribute their work towards the improvements in WLANs. The high throughput has been achieved via many enhancements in both the physical (PHY) and MAC layers. The work carried out in this paper also describes the modifications that can be incorporated at the MAC for the improvement of throughput. In this paper Aggregation with capture effect scheme is considered which shows the improvement in the throughput of the system. When aggregation scheme is used the overheads is minimized and efficiency and channel utilization is improved. Now by combining capture effect along with aggregation the performance is still made better. The analytic model is developed for the system with and without capture effect and then simulated with MATLAB**

Keywords- Wireless LAN (WLAN), High-Throughput, Medium access Control, IEEE 802.11, Aggregation, Capture effect

I. INTRODUCTION

The 802.11 WLANs interconnects wireless devices and also help wireless devices interfacing with wider internet through the access point. The challenges of WLANs involves many researchers to actively engross and contribute their work for the improvements in this area. One such challenge of wlans is throughput. There are various methods suggested for improving the throughput in wlans such as collision probability estimate, retransmission time out, Scheduling random access, congestion control method etc. The recent proposals infers to support high physical rate[10 whereas the performance of the system is mainly hampered due to the presence of large overheads for MAC and physical layer operations. Many studies on the wlans specifies that MAC efficiency of 802.11 typically decreases with increasing PHY rate [1],[3] since increasing PHY rates leads to faster transmission of the MAC frame payload, but overhead such as physical headers and contention time typically does not decrease at the same rate and thus overheads dominates frame transmission times as seen in figure 1. This infers that further effort is required in terms of the protocol efficiency of the 802.11 MAC. The Aggregation is one such method used in MAC for throughput improvement. Here multiple MAC frames are combined together to form a large aggregated frame, which includes additional overheads due to aggregation but reducing the overall overheads. Here if any errors occur during the transmission operation the corrupted fragments of the aggregated frame are retransmitted. The aggregated frame is made by combining multiple packets in a specific manner and transmitted in the channel as a single large frame. Here, we use the mechanism proposed in[5] where increase in transmission delays are unavoidable to achieve high throughput. When transmitting frames on the channel there are situations where the frames transmitted by one system may collide with other system frame(s) thereby causing damage to the frame that involve in collision and retransmission of the collided frames happen. This situation also leads to decrease in system(s) performance if more collisions are involved. To overcome the above situation only one user is to be provided access to the channel at a time which is practically not feasible. In order the handle the situation in a much better way capture effect is used. Capture effect manages the situation effectively by considering the energy of the frames that involve in collision. Here a capture threshold is considered which is compared with the energy level and based on the comparison one of the collided frame can be recovered in most of the situations. This improves the performance of the system. Along with aggregation capture effect is used to facilitate the high throughput.

II. METHODOLOGY

The importance of the Aggregation scheme is discussed and this paper describes the capture effects importance and use of capture effect along with aggregation for improving the performance of the system. The paper models capture effect and analysis of the same with matlab is also shown in the upcoming sections

A. AGGREGATION

The DCF scheme [2], has only one packet in each frame, so the packet size and the payload size of one frame are the same. Every frame transmitted unavoidably includes an overhead with additional time Tohp. This overhead includes the time Tphdr required to transmit the physical header, Tmhdr the time to transmit the MAC header, Tcw the CSMA/CA back-off time (contention window), and tack the time Tack to transmit a MAC acknowledgement. As the PHY rate increases, the contention time Tcw does not decrease towards zero due to the constraints placed on the minimum slot size by clock synchronization requirements and on DIFS by the need for backward compatibility.

Aggregation schemes[5] seek to repay the physical header overhead across multiple packets. This is achieved by combining multiple packets. Normally when large frames are transmitted the throughput tends to decrease due to the large frame retransmission but in the aggregation scheme used in this paper the disadvantage of the large frame transmission is taken care by identifying the corrupted fragment of the large frame and retransmitting only the corrupted fragment such partial retransmission could be expected to improve performance. By considering the above method we see that the throughput can be increased to a much better levelThere are certain things that is to be considered such as what should be the max size of the packet, what should be the maximum waiting time for aggregation to take place at transmitter side before sending the aggregated frame etc., In aggregation multiple packets are aggregated [7] into a single large frame and, should an error occur, the damaged packets are retransmitted. These support similar functionalities to our scheme, with a special delimiter for locating each fragment in a frame.

The aggregation technique is used to solve an unfairness problem in WLANs. Aggregation involves making of a aggregate packets by combining packets coming from the upper layer. During aggregation of packets the fragmentation threshold are maintained and the aggregated frame may have one or more fragments in it. The MAC layer transmits the large frames and retransmits only fragments when errors are detected by their Frame Check Sequence (FCSs). An adaptive waiting mechanism, is considered here in which the MAC layer never deliberately waits for packets to aggregate, and a transmission is started whenever MAC wins the Transmission opportunity. When packets are large and arrive rapidly from the upper layer, it is straight forward for the MAC layer to assemble these into large frames. The MAC aggregates the packets coming from the upper layer considering the max size of the frame and waiting delay, if the size reaches the maximum the frame aggregation is stopped accordingly and the next aggregation frame is built. Secondly if the packets coming from the upper layer are slow and if the MAC wins the transmission opportunity then MAC does not wait for the large frame to build it starts transmitting. A frame is formed by aggregating the currently queued packets. Both these conditions are to be satisfied accordingly, which describes the scheme used

At the receiver side the If errors happen during the transmission, only the corrupted fragments of the large frame are retransmitted. An analytic model is developed to evaluate the throughput over a noisy channel with the help of [2],[3],[8] and [9]. Fragmentation plays a central role in aggregation with fragments being the unit used for retransmission. Optimal frame and fragment sizes can also be calculated using this model. The simulation of normal transmission and aggregation scheme[4] both are evaluated and compared in the previous work.

B. Capture Effect

To retain the design simple and to reduce the cost, IEEE 802.11 did not pay special attention to the capture effect. When a first frame arrives at a receiver and then, the second frame arrives before the first frame reception is still ongoing. Here if the receiver detects an increase in energy due to the overlapping of frames, this may result in two consequences which depends on the magnitude of increased energy. If the increase in energy is more than a specified threshold, which is called the capture threshold, then the receiver gives up the first data frame and may try to receive the second data frame in the message in message (MIM) mode. In this case, the retraining process begins by seeking to synchronize with, and the second frame is demodulated. If the increased energy is less than the specified threshold, then the receiver retains the first frame.

The authors in [10] have carried out a measurement study that shows the terms and conditions (power difference, timing, bit rate) in which this capture effect takes place. Depending on the arrival timing and the relative signal power of the involved frames, any one frame can survive the collision and can be successfully received at the receiver. A recent measurement work on the capture effect in 802.11 networks argues that if frame is stronger ,it can be successfully decoded only in two cases: (1) The stronger frame arrives earlier than the weaker frame, or (2) the stronger frame arrives later than the weaker frame but within the preamble time of the weaker frame. The authors have shown that the stronger frame can be decoded correctly regardless of the timing relation with the weaker frame. In explaining various capture cases we observe that the successful capture of a frame involved in a collision is determined through two stages: the preamble detection and the frame check sequence (FCS) check. They presented the precise terms and conditions (timing, SIR, and PHY bit rate) in which the receiver can successfully decode a packet from a sender despite the simultaneous transmission by another sender. They explained different capture cases and observed that the successful capture of the frames involved in collisions are explained by two stages: The first one is the preamble detection and the second one is the frame check sequence (FCS) check.The capture effect involves retraining, which starts if the energy increase is above the capture threshold given . The retraining continues when the carrier or the preamble of the new frame is detected. After this preamble detection stage, the frame header and frame body must be received successfully in the presence of interference from other transmissions and from other external noise sources. Otherwise, the frame check sequence (FCS) at the end of the frame must be succeeded: It is called as FCS check stage. The capture of a frame involved in a collision is determined by two stages: preamble detection and frame body FCS check. The two-stage capture model is supported by their measurement-based on observations . The analysis of their experiments helped for better understanding the interference / capture and their impact on the throughput, which is important for the further design and the improvement of the network protocols and wireless network capacity.

When the WLAN is considered, where the nodes are within medium sense thus the RTS/CTS methods are not necessary, and if ideal channel conditions are assumed then the losses are only caused by collisions. Without loss, the stations are assumed to send fixed size data packets and employ the single PHY rate. The analysis of the 802.11 MAC behavior with heterogeneous capture, which distinguishes two classes of nodes that experience different capture probabilities , the analysis may be easily extended for accounting the multiple groups of stations by augmenting with the suitable set of rules. At AP, the nodes in the Class 1 can capture the channel over the nodes in Class 2. Therefore, when the concurrent transmissions occur, the following outcomes are possible.

• When the station in Class 1 and the node in Class 2 transmit then the station in Class 1 captures with probability α; transmission of the station in Class 2 fails;

• If the station in Class 2 simultaneously transmits with any other station then transmission fails.

In the analysis, the capture probability “alpha” is as a model parameter, when the methods can be employed for accurate estimation. The throughput performance of the different network loads in the presence of capture, are identified and the scenarios in which all classes of stations can benefit from the effect.

III. PERFORMANCE ANALYSIS(MODELING) OF 802.11 WITH CAPTURE (THROUGHPUT MODEL)

A realistic model is proposed for 802.11 operations that, allows nodes with heterogeneous capture probabilities. Whereas in the absence of capture effect, simultaneous frame transmissions fail due to collisions. In this case, the conditional failure (collision) probability p experienced by a transmitted frame is expressed mathematically as shown in the equation (1) given below.

$$p=1-(1-\tau)^{(n-1)} \quad (1)$$

where,

τ = the probability(stationary) that a station transmits in a randomly chosen slot time.

n = number of stations in the WLAN.

A transmission of a station can still become successful even when another station transmits simultaneously in the presence of the capture effect provided only the frame received with a higher signal level will be decoded by the access point, while the other transmission will result in failure. Considering the conditional failure probabilities for the two classes of stations be denoted by p1 and p2 the corresponding transmission probabilities of stations in Class 1 and Class 2 are given by $\tau 1$ and $\tau 2$, respectively, and can be expressed as follows:

$$1-p1=(1-\tau1)(n1-1)(1-\tau2)n2+(1-\tau1)(n1-1)(1-(1-\tau2)n2)*alpha, \quad (2)$$

$$1-p2 = (1-\tau1)\ n1(1-\tau2)(n2-1) \quad (3)$$

where,

alpha is the probability that a station from Class 1 captures the channel over stations from Class 2. The failure probability can also be expressed in another form which is computed by subtracting a capture probability from the collision probability, i.e.

$$p=1-(1-\tau)^{(n-1)}-Pcap \quad (4)$$

Let p be a station`s conditional failure probability. The expected number of attempts to transmit a packet is expressed as shown in equation 6.3 below

$$E(R)= 1+p+p2+p3...+pK \quad (5)$$

where,

K= the maximum number of retry attempts.

During back off the expected number of slots is given by

$$E(X)= ti+b0+pb1+p2b2+...+pkbk \quad (6)$$

where,

bi=The mean length of back off stage i expressed in slots

ti =The mean idle time that a station waits for a packet after transmission.

Thus, we can express the transmission attempt rate of the station as

$$\tau=E(R)/E(X)$$

$$= [1+p+p2+p3...+pK\ ] /[ti+b0+pb1+p2b2+...+pkbk\ ] \quad (7)$$

Neglecting post-back off and assuming no buffering, we can express the mean idle time that a station waits for the packet after transmission as

$$ti =q(1+2(1-q)+3(1-q)2+...) = 1/q \quad (8)$$

where,

q= probability that a new frame arrives in a uniform slot time Es, given by

$$Es =Pi\sigma+Ps\ Ts+ Pf\ Tf \quad (9)$$

where,

σ = average durations of an idle slot

Ts = average duration of a successful transmission

Tf = average duration of a failure.

Pi, Ps and Pf are the corresponding probabilities, given by

$$Pi = (1-\tau1)n1\ 1-\tau2)n2 \quad (10)$$

$$Ps = n1\tau1(1-p1)+n2\tau2(1-p2) \quad (11)$$

$$Pf = 1-Pi-Ps \quad (12)$$

The average duration of successful and failure of transmission ‘Ts’ and ‘Tf’ can be expressed as

$$Ts = TPLCP + E[L]/C + SIFS + TACK + DIFS, \quad (13)$$

$$Tf = TPLCP + E[L]/C + TACK\_timeout, \quad (14)$$

where,

TPLCP = duration of the PLCP (Physical Layer Convergence Protocol) preamble and headers.

L =average frame length.

C = PHY rate

TACK= duration of an acknowledgment.

By CWmax = 2m CWmin and using W = CWmin to simplify notation, we have bk= 2kW/2, for all values of $k \geq 0$ and assuming infinite back off ($K \rightarrow \infty$), we obtain

$$\tau1 = 2(1-2p1) /(W(1-p1-p1(2p1)m)+2(1-2p1)(1-p1) q) \quad (15)$$

$$\tau2 = 2(1-2p2) /(W(1-p2-p2(2p2)m)+2(1-2p2)(1-p2) q) \quad (16)$$

Using the mathematical equations described above we can solve ($\tau1$, p1, $\tau2$, p2) and compute the total throughput of the network as follows:

$$S = Ps*E[P]/Es \quad (17)$$

where,

E[P] = expected size of the payload.

By using the above equations which represents the throughput model of the system the system performance is computed as shown in Table 1.

TABLE I. COMPARISON OF SYSTEM WITH AND WITHOUT CAPTURE EFFECT

Per Class Offered load in Mbps	Normalized Throughput of system without capture effect	Normalized Throughput of system with capture effect
1	0.597526523344680	0.602745912855349
2	0.597526562455457	0.602745952697344
3	0.597526575492384	0.602745965978010
4	0.597526582010848	0.602745972618343
5	0.597526585921926	0.602745976602543
6	0.597526588529312	0.602745979258677

When combining both the above techniques aggregation and capture effect the system under conseideration shows better performance as seen in figure 1

When modeling the aggregation with capture effect we consider the equation mentioned below

$$p1=1-((1-t1)^{\wedge}(n1-1)*(1-t2)^{\wedge}(n2))+((1-t1)^{\wedge}(n1-1) *(1-((1- t2)^{\wedge}n2))*alpha) \quad (18)$$

$$p2=1-(1-t1)^{\wedge}n1*((1-t2)^{\wedge}(n2-1)) \quad (19)$$

$$Pi=((1-t1)^{\wedge}n1)*((1-t2)^{\wedge}n2) \quad (20)$$

$$Ps=(n1*t1*(1-p1))+(n2*t2*(1-p2)) \quad (21)$$

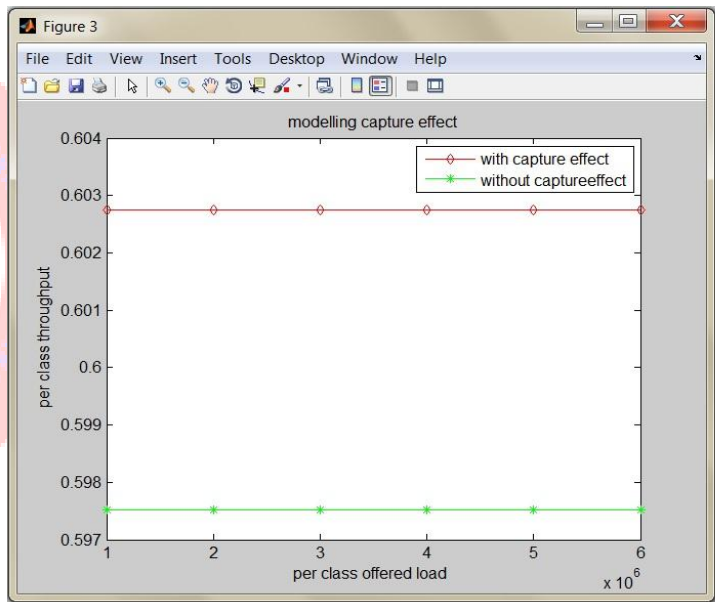

Figure 1. Performance comparison with and without capture effect

$$Pf=1-Pi-Ps \quad (22)$$

$$Es=(Pi.*si)+(Ps.*Ts)+(Pf.*Tf)$$

$$si=(20*10^{\wedge}-6)$$

$$EL=LF.*(1-PEFRAG1) \quad (23)$$

TABLE II. COMPARISON OF SYSTEM WITH AND WITHOUT CAPTURE EFFECT

Per Class Offered load in Mbps	Per class Throughput ‘S’ (Aggregation without capture	Per class Throughput ‘SA’ (Aggregation with capture effect)

	effect)	
1	0.6582	0.7211
2	0.6499	0.7120
3	0.6334	0.6940
4	0.6018	0.6593
5	0.5432	0.5952

The throughput for the system when aggregation and capture effect is used together is given by

SA=(Ps.*EL)./Es (24)

alpha is the probability that station 1 captures channel of station 2 which is used as an important parameter to differentiate the Aggregation system using capture effect(alpha=0.75) and not using capture effect(alpha=0). The performance comparison is shown in figure 2

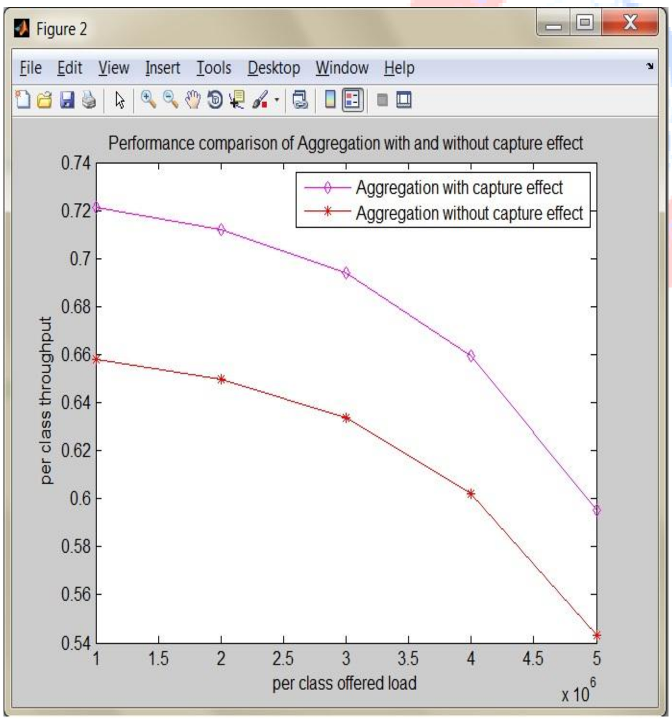

Figure 2. Performance Comparison of Aggregation with and without Capture effect

IV. CONCLUSION

This paper focuses on modeling capture effect and analyzing the importance of capture effect. The simulation of the same clearly shows that capture effect has better system performance as shown in figure 1. Considering the importance of capture effect with the previously modeled aggregation system[4] the improvement of the system is also analyzed and is clearly shown in figure 2. The aggregation with capture effect has an improvement in the system performance when compared to that of only aggregation. The simulation is done with the help of MATLAB considering the mathematical model as described.

The paper has incorporated single layer aggregation which shows considerable improvement. By incorporating other methods such as multilayer aggregation contention window adjustment the performance of the system can be studied. By simulations we examine the aggregation with capture effect technique can be used in wireless LANs for better performance of realistic application traffic.

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