IRACST – International Journal of Computer Networks and Wireless Communications (IJCNWC), ISSN: 2250-3501
Vol.3, No6, December 2013

Analysis of Throughput in WLANS considering Aggregation scheme using Mathematical modeling (MATLAB)

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***Abstract*—Wireless local area network (WLAN) links two or more devices using some wireless distribution method, and usually providing a connection through an access point to the wider Internet. The basic requirement of the Wireless LAN is to achieve higher throughput at the medium access control (MAC) service access point. The throughput or network throughput is the average rate of successful message delivery on a communication channel. This high throughput has been achieved via many enhancements in both the physical (PHY) and MAC layers. One such enhancement is aggregation of frames, which thereby minimizes the overheads and improves the efficiency of channel utilization. In this paper we use the aggregation scheme to achieve high efficiency at MAC layer satisfying the properties of any CSMA/CA. The analytic model is developed considering the aggregation over a noisy channel and various performance measures such as MAC efficiency, saturation throughput and channel utilization are simulated with MATLAB**

Keywords-High-Throughput, Medium access Control, Wireless LAN (WLAN), IEEE 802.11, Channel utilization

I. INTRODUCTION

The 802.11 standard focuses on achieving high throughput introducing many enhancements in both medium access control and physical layers. Recent 802.11 proposals infers to support high PHY rates [10], [11]. Due to the large overhead for medium access control (MAC) and physical operations the throughput performance is reduced. For eg., the maximum achievable throughput of the 802.11 distributed coordination function (DCF) is only about 30 Mb/s. As specified in [3] if the physical rate is simply increased (up to infinity) without reducing the addressed overhead, the enhanced throughput is bounded around 100 Mb/s. We know that the MAC efficiency of 802.11 typically decreases with increasing PHY rate [1] 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. 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. A Mathematical model is developed to evaluate the throughput of the aggregated scheme over noisy channels and to evaluate throughput and delay performance. To avoid redesign of MAC repeatedly, we need to see whether it is feasible to extend the 802.11 MAC to maintain high throughput efficiency regardless of PHY rates. In particular, we consider fundamental properties that must be satisfied by any CSMA/CA based MAC layer and develop Aggregation scheme. In this scheme, multiple packets are combined in a specific manner and transmitted in as a single large frame. Here, we use the mechanism proposed in[5] where increase in transmission delays are unavoidable to achieve high throughput. This transmission delay is to an extent reduced by using zero waiting mechanism, where the frames are immediately transmitted once the MAC wins a transmission opportunity. By doing this the frame sizes adapt automatically to the physical rate and channel state, thereby maximizing the throughput efficiency while minimizing the holding delay.

II. METHODOLOGY

The paper describes the DCF scheme and the Aggregation scheme in this section and the simulation of the same is seen in the next sections further described. The paper has also taken measures to evaluate the Channel Utilization and the simulation results with matlab is also shown in the upcoming sections

A. DCF scheme

The DCF scheme [2],has only one packet in each frame, so the packetsize 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, Tmhdrthe time to transmit the MAC header, Tcw theCSMA/CA back-off time (contention window), and tack the time Tack to transmita MAC ACK (Notation is listed in Table 1). As the PHY rate increases, the contention time Tcw doesnot decrease towards zero due to the constraints placed on theminimum slot size by clock synchronization requirements andon DIFS by the need for backward compatibility.

B. AGGREGATION

Aggregation schemes 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 level.

The test method of normal transmission and aggregation scheme both are evaluated and compared. This is a key motivation of the work presented here. The physical layer has to transmit very large frames, and has to continue decoding even if the BER exceeds some previously unacceptable value. Under these conditions, the size of the largest practical frame is still unknown. From the MAC viewpoint, any retransmission scheme carries an associated signaling overhead and hence a trade-off exists between system efficiency and the granularity of retransmission. There 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. Removing the DIFS, SIFS and back offs before a series of packets, transmitting the packets together in a large physicallayer frame, as shown in Fig.1.

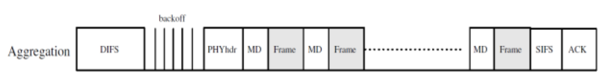

Figure 1. Aggregation

C. Methodology in Aggregation scheme

The basic idea of the scheme [5] is to aggregate packets from the upper layer into large frames. Packets that exceed the fragmentation threshold are segmented into fragments. Then the MAC layer transmits the large frames and retransmits only fragments when errors are detected by their Frame Check Sequence (FCSs). The flow chart of what is done at the transmitter side is give below.Large frame sizes are used in the scheme, thus if the packets from the upper layer have small sizes, then a proper waiting mechanism is used.

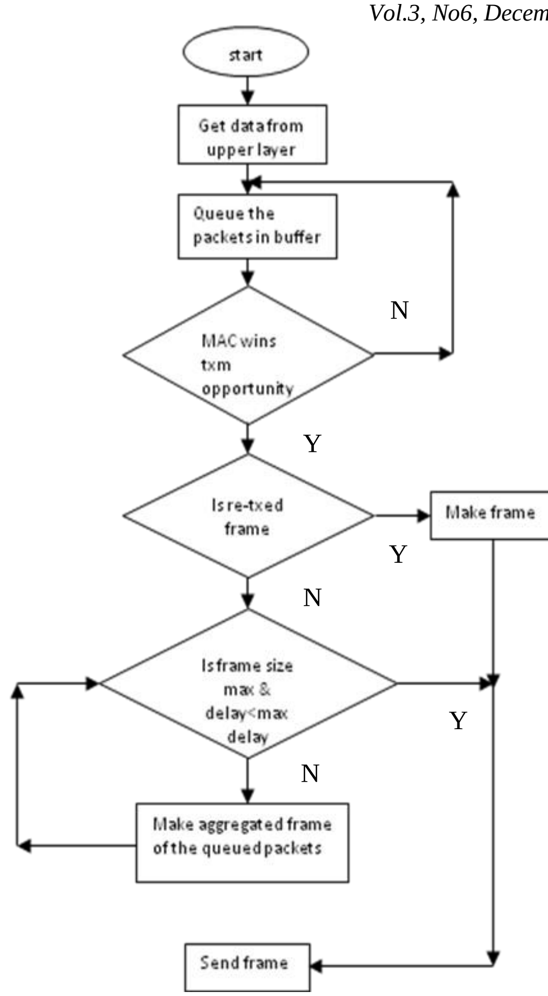

Figure 2. Flow chart(Transmitter)

Here this paper suggests an adaptive waiting mechanism, 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

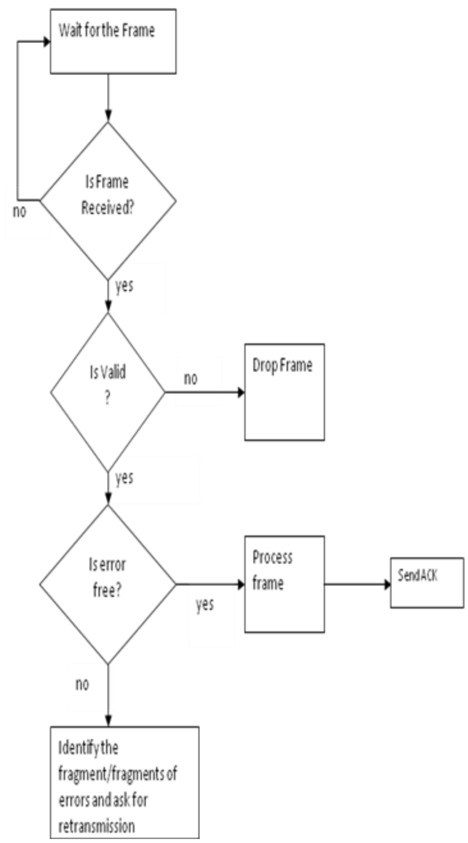

Figure 3. Flow chart(Receiver)

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. 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.

In this paper an additional performance measure is evaluated called channel utilization.Channel utilization [4] is the use of the channel disregarding the throughput. It counts not only with the data bits but also with the overhead that makes use of the channel. The transmission overhead consists of preamble sequences, frame headers and acknowledge packets. The definitions assume a noiseless channel. Otherwise, the throughput would not be only associated to the nature (efficiency) of the protocol but also to retransmissions resultant from quality of the channel.

III. MATHEMATICAL MODELLING AND SIMULATION WITH MATLAB

In order to study the various characteristics MATLAB is used and the simulations are performed. Various notations are used to represent different parameters and is listed below in the Table 1.

TABLE I. NOTATIONS USED IN THIS PAPER

Parameter	***Description***
Tp	Time duration to transmit one packet
Tphdr	Time duration to transmit the PHY header on one frame
Tmhdr	Time duration to transmit the MAC header on one frame
Tack	Overhead for transmitting an ACK frame
Tdifs	DCF interframe space Time
Tsifs	Short interframe space Time
Track	Time duration to transmit an ACK frame
Lp	Packet size(bytes)
R	Physical rate
R1	Link rate
tphy	Physical layer time slot
tf	Time duration to transmit payload of one frame
eqk	Queue size
Alfa	Level of load
smax	Maximum throughput
tphy	Physical layer time slot
Ptrans	Transmission probability
n	Number of stations
Lf	Payload size in one frame(bytes)
Lfrag	Fragment size(bytes)
Lfcs	FCS size (bytes)
Lfhdr	Length of fragment header (bytes)
tb	Average time of backing off
Cu	Channel utilization
N	Number of frames in a block
L	Length of a payload(bit)

The MAC throughput efficiency is defined as:

eff=Tp/(Tp+Tohp) (1)

Where Tp is the time required to physically transmit a packet (i.e., the frame payload). This is given by the equation (2)

Tohp=Tphdr+Tmhdr+Tcw+ Tack (2)

Where Tack is defined as

$$\text{Tack} = \text{Tsifs} + \text{Tphdr} + \text{Track} + \text{Tdifs} \quad (2a)$$

As discussed earlier if the physical rate R increases, for a fixed packet size Lp,the time to transmit the packet payload decreases.If the time Tohp doesnot also decrease thenthe efficiencyeff→ 0 as R → 1.

$$\text{Tp} = \text{Lp}/\text{R} \quad (3)$$

Using (3) the per packet throughput efficiency is

$$\text{eff} = (\text{Lp}/\text{R})/(\text{Lp}/\text{R}+\text{Tohp}) \quad (4)$$

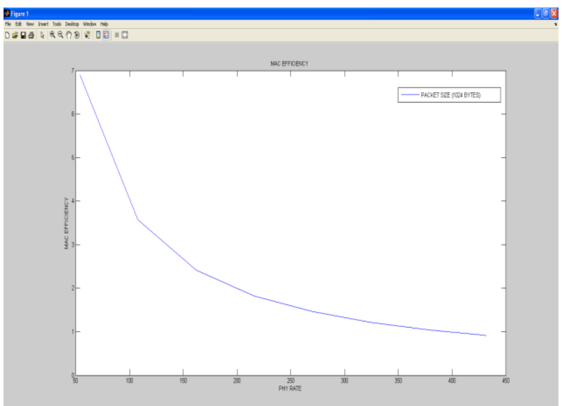

Figure 4. MAC Efficiency

Using the above conditions it is noticed in Fig.4 the inefficiency of MAC as we increase the physical rate.

In a simplistic approach, it is considered channel efficiency can be equal to channel utilization assuming that acknowledge packets are zero-length and that the communications provider will not see any bandwidth relative to retransmissions or headers.

The analytical model is obtained considering [2], [3], [8] and [9].There is three kinds of event in the Aggregation scheme as described in [5].

Idle duration TI: When all STAs are counting down, no station transmits a frame and we have

$$\text{T1} = \text{tphy} \quad (5)$$

Success/Error duration T3: When a frame is successfully transmitted or it is corrupted due to channel noise, the slot duration is the sum of a frame, a SIFS and ACK duration.

$$\text{T3} = \text{Tphdr} + \text{Tf} + \text{Tack} \quad (6)$$

Collision duration TC: When two or more stations transmit at the same time a collision occurs. In this case the sender waits for an EIFS before the next transmission and so

$$\text{TC} = \text{Tphdr} + \text{Tf} + \text{Teifs} \quad (7)$$

The expected state duration is

$$\text{ET} = \text{P1T1} + \text{P3T3} + \text{PCTC} \quad (8)$$

Where PI , P3, PC are the probabilities of Idle, Success/Error and Collision events respectively. Let 'Ptrans' denote the STA transmission probability and n the number of STAs in the system.

$$\text{P1} = (1-\text{Ptrans})^{n} \quad (9)$$

$$\text{P3} = n*\text{Ptrans}*(1-\text{Ptrans})^{n-1} \quad (10)$$

$$\text{PC} = 1-\text{P1}-\text{P3} \quad (11)$$

In this scheme, the receiver sends back the ACK frame in both the successful and erroneous cases, thus pf = pc and the Bianchi's formula[2] could in fact be applied without change. We note that Bianchi assumes that a frame can be retransmitted infinite times, which is inconsistent with the 802.11 specification [3]. Solving for Ptrans we can obtain the saturation throughput SAGG of the scheme from

$$\text{SAGG} = \text{P3}*\text{EL}/(\text{P1T1}+\text{P3T3}+\text{PCTC}) \quad (12)$$

where ELis expected number of successfully transmitted bits – recall that the AFR scheme allows successfully transmitted fragments to be received even if some fragments within a frame are corrupted is given in terms of fragment error rate Pefrag and length of full frame Lf by

$$\text{L} = \text{Lf}(1-\text{Pefrag}) \quad (12a)$$

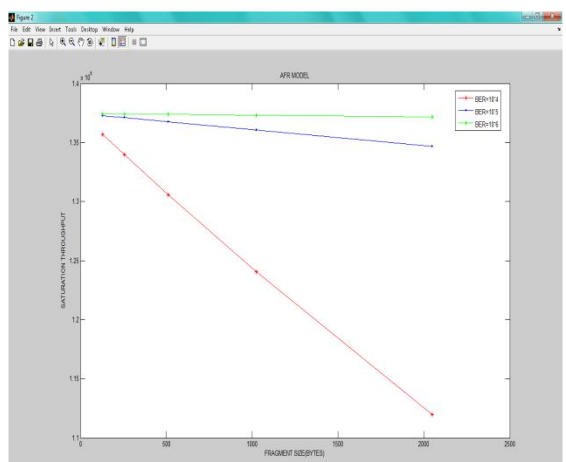

Figure 5. Aggregation model

As the frame size Lf →∞, we have that (since T3=TC)

$$\text{SAGG} = [\text{P3}*(1-\text{Pefrag})]/[(1-\text{P1})*(\text{A}*8*\text{symbol})/\text{Ndbps}] \quad (13)$$

Where A is given by A= (Lfrag+Lfcs+Lfhdr)/Lfrag)

By using the above conditions the we obtain Fig.4 and Fig.5

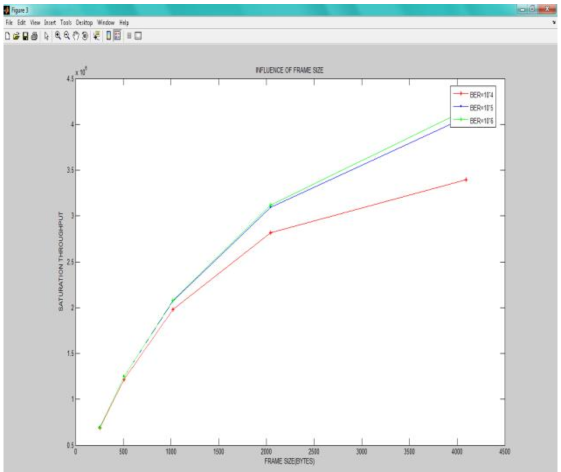

Figure 6. Influence of Frame Size on Saturation Throughput

Considering Block acknowledgement scheme[4] the amount of channel utilization is measured for various BER.

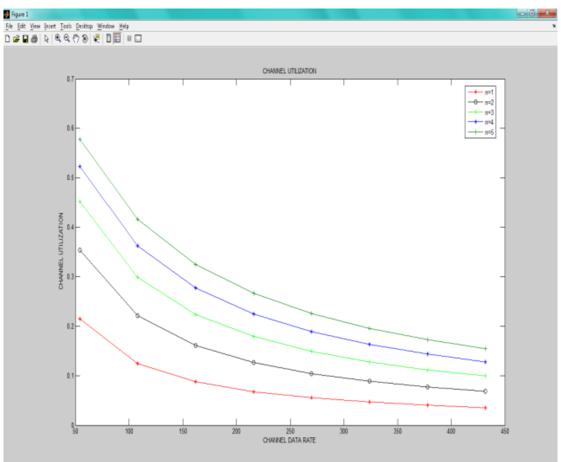

Figure 7. Channel Utilization

The channel utilization (Cu) is calculated for this scheme with the consideration of data rate R1as a parameter and is as described.

$$\mathbf{Cu} = \frac{\mathbf{1}}{\dfrac{\mathbf{R1}}{(\mathbf{N} * \mathbf{L})\left(\mathbf{Tb} + \left(\dfrac{\mathbf{Cd}}{\mathbf{R1}} + \mathbf{Cid} + \mathbf{N} * \mathbf{sifs}\right)\right)} + \mathbf{1}}$$

(14)

whereC_d and C_{id} is the dependent control overhead rate (like *RTS/CTS BlockACKReq/BlockACK*payload bits) and independent control overhead rate (like SIFS, DIFS, physical header, etc.). By using all the above equations we have obtained the simulated results for different values of N as shown in Fig.6.

IV. CONCLUSION

The paper described above shows various performance measures such as MAC efficiency saturation throughput, channel utilization etc. The simulation is done with the help of MATLAB considering the mathematical model as described. The simulation is done considering one transmitting and one receiving station. The channel utilization under different channel data rates and different aggregation constant employing the block ACK based aggregation as a complement to the theoretical analysis.

The paper is a ground work and can be enhanced for multiple station communication, multi-rate operation, Multilayer aggregation etc., The optimal frame size for aggregated frame, contention window adjustments and capture effect is not evaluated and can also be considered as improvements in the subsequent papers. The zero-waiting time for frame transmission can achieve maximum throughput as shown. By simulations we examine the aggregationtechnique can be used in wireless LANs for better performance of realistic application traffic with different requirements.

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Authors Profile

I B.MadhuriBhushan, a Research scholar in the Department of Instrumentation, SK University,Anantapur. I am currently carrying out my research work in the area of wireless communication and analyzing on the performance issues in WLANs under the guidance of Professor B. Rama Murthy. I have presented two papers in the National conference in the same field with different proposed methods.