ANALYSIS OF SATURATION THROUGHPUT AND DELAY OF IEEE802.11B WLANS USING VARIOUS ALGORITHMS

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Abstract

Wireless communications is, by any measure, the fastest growing segment of the communications industry. IEEE 802.11b (also referred to as 802.11 High Rate or Wi-Fi) is an extension to 802.11 that applies to wireless LANS and provides 11 Mbps transmission in the 2.4 GHz band. IEEE 802.11 allows for fragmentation tuning and rate selection to achieve highest throughput. Fragmentation is the process by which 802.11 frames are partitioned into smaller fragments that are transmitted separately to the destination. The destination station reassembles the fragments back into the original frame. Throughput is the average rate of successful message delivery over a communication channel. The aim of this thesis is to analyze the performance of IEEE 802.11 wireless networks in terms of throughput and packet delay using two different algorithms Constant contention window and Binary Exponential Back-off and also to determine the optimal Fragment size and Contention window that improves the throughput and delay over fading channels.

Keywords- IEEE *802.11b, fragmentation, Throughput, Constant Contention Window, BEB*

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I. INTRODUCTION

In communication networks, such as Ethernet or packet radio, throughput or network throughput is the average rate of successful data delivery over a communication channel. This data may be delivered over a physical or logical link, or pass through a certain network node. The throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second or data packets per slot. The system throughput or aggregate throughput is the sum of the data rates that are delivered to all the terminals in a network.

The IEEE 802.11 family is an increasingly popular WLAN standard. The IEEE 802.11 standard [1] provides two medium access methods: the Distributed Coordination Function (DCF) also known as the basic access method and the Point Coordination Function (PCF) which uses a point coordinator to arbitrate the access right among nodes. DCF is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) and supports only best effort service. DCF distributes the control of the channel through a set of listen and wait procedures observed by every station. Today's WLANs are rate adaptive in which stations can transfer data at a number of transmission rates. IEEE 802.11 standards support multirate enhancement and data transmission can take place at various rates according to channel conditions.

In the IEEE 802.11 standard MAC protocol, the Binary Exponential Back-off (BEB) algorithm is used. In BEB, when a node over the network has a packet to send, it first senses the channel using a carrier sensing technique. If the channel is found to be idle and not being used by any other node, the node is granted access to start transmitting. Otherwise, the node waits for an inter-frame space and the back-off mechanism is invoked. A random back-off time will be chosen in the range [0, CW-1]. A uniform random distribution is used here, where CW is the current contention window size. If the medium is determined to be busy during back-off, then the back-off timer is suspended. This means that back-off period is counted in terms of idle time slots. Whenever the medium is determined to be idle for longer than an inter-frame space, back-off is resumed. When back-off is finished with a BO value of zero, a transfer should take place. If the node succeeded to send a packet and receive an acknowledgment for it, then the CW for this node is reset to the minimum, which is equal to 31 in the case of BEB. If the transfer fails, the node goes into another back-off period. When going for another back-off period again, the contention window size is exponentially increased with a maximum of 1023.

The Constant contention Window Algorithm is the modification of the IEEE 802.11 BEB algorithm, which is used to control the contention window in the case of collisions, in order to provide a better Throughput. In case of collisions, the contention window size is selected between [0 to CW] and CW is fixed for every retry. The value of CW is selected between CW_{min} and CW_{max}.

The IEEE 802.11b standard approved in 1999, allows for frame fragmentation. Fragmentation is the process by which 802.11 frames are partitioned into smaller fragments that are transmitted separately to the destination. The destination station reassembles the fragments back into the original frame. The WLAN fragmentation and reassembly mechanisms operate at the MAC layer. Only unicast frames are allowed to be fragmented. Each fragmented frame is encapsulated with the usual MAC header and FCS fields and each fragment must be individually acknowledged. For these reasons the fragmentation mechanism decreases the payload to overhead ratio.

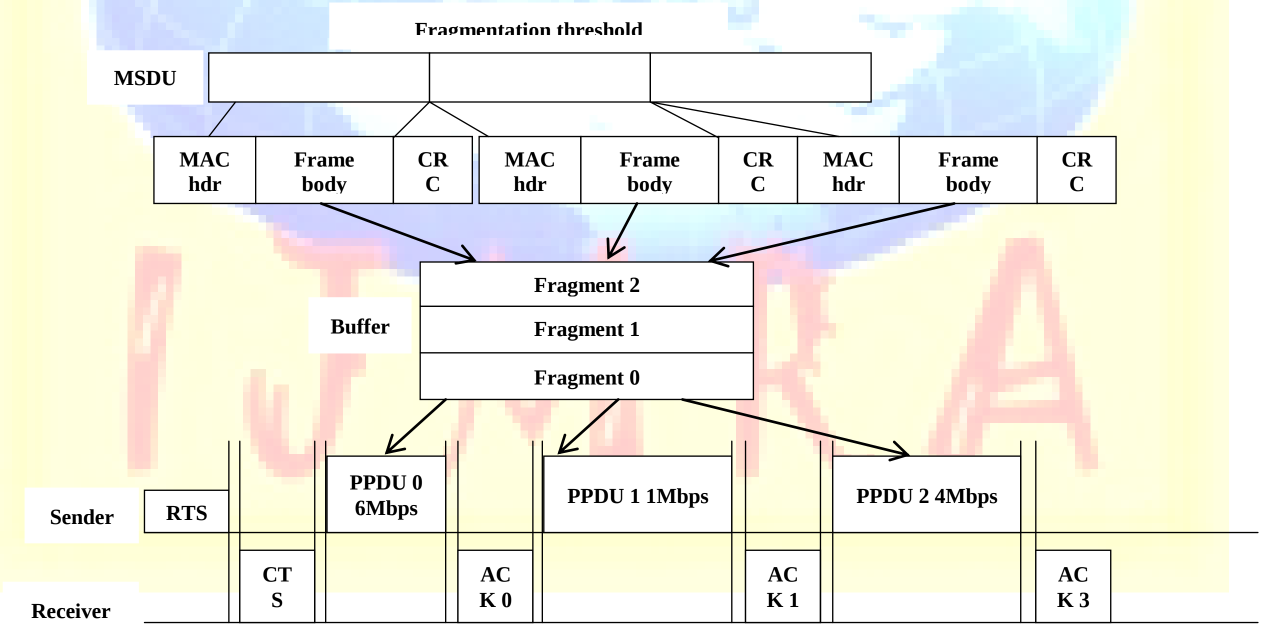

Figure1 Conventional fragmentation process and timeline of data transmission with rate Adaptation

However, fragmentation can enhance the throughput efficiency in cases where channel conditions limit the probability of successfully delivering large frames. In this paper the influence of fragmentation on the throughput performance of IEEE 802.11b networks is analyzed. It is also shown that by properly tuning the fragment size (i.e. the fragmentation threshold parameter) it is possible to optimize the throughput.

Fragmentation is the process of dividing a long frame into short frames. Fig. 1 illustrates the fragmentation process in IEEE 802.11 MAC. MSDU is passed down from the LLC layer, if the size of the MSDU is greater than the fragmentation threshold and it is divided into smaller fragments. Each fragment, namely an MPDU, becomes a MAC layer frame with a MAC header. Then, a physical layer convergence protocol (PLCP) header and a preamble are added to the MPDU. The resulting frame is called a PLCP protocol data unit (PPDU), which is the frame transmitted by the physical layer over the air.

All fragments are sent independently, each of which is separately acknowledged. Once a sender contends for and seizes the medium, it will continue to send fragments with SIFS size gaps between the ACK reception and the start of the subsequent fragment transmission until either all the fragments of the MSDU have been sent or an ACK is not received.

When the transmission of a fragment fails, the contention process begins after a DIFS idle time period. The remaining fragments are transmitted when the node seizes the channel again through the contention process. The transmission process for the fragments of an MSDU is called a fragment burst. Because the header of each MAC frame contains the information that defines the duration of the next transmission, the nodes that overhead the header update the NAV value for the next fragment transmission.

II. THROUGHPUT ANALYSIS

The performance of the wireless Communication network can be evaluated in terms of QOS parameters like throughput, packet delay and packet delivery ratio, packet drop etc. (2, 3).Let n be the fixed number of contending stations and τ be the probability that a station transmits the packets in a randomly chosen slot time. Since a station transmits when its back-off timer reaches the value of zero, the equation for τ using BEB can be written as

$$\tau = \frac{2.(1-2p).(1-p)}{w.\left(1-(2p)^{m+1}\right).(1-p)+(1-2p).\left(1-p^{m+1}\right)} \quad (1)$$

Where P is the probability of collision W is the contention window size and m is the retry limit. According to Bianchi, the probability τ that a station transmits in a randomly chosen slot time is using Constant contention window is given as

$$\tau = \frac{2}{CW+1} \quad (2)$$

Where CW is the size of the contention window.

The probability that there is no transmission in a given slot time is:

$$P_n = (1-\tau)^n \quad (3)$$

The probability that at least one station transmits during slot time i.e. probability that the channel is busy is given as $P_b = 1-(1-\tau)^n$ (4)

The total number of idle slots is given as $\frac{1}{P_b}-1$

Hence the total time that the node spends in idle state is

$$T_{idle} = \left(\frac{1}{P_b}-1\right) * slottime \quad (5)$$

Where *slot time* is the idle slot time.

Collision occurs to the packets transmitted by the station A when any one of the *n*-1 nodes transmits. Now the probability of collision P_c or the probability of any one of the *n-1* nodes transmitting a packet P_{tr} in an idle time can be expressed as

$$P_c = P_{tr} = 1-(1-\tau)^{n-1} \quad (6)$$

The probability of successful transmission, P_s can be expressed as:

$$P_s = \frac{n\tau(1-\tau)^{n-1}}{1-(1-\tau)^n} \quad (7)$$

The throughput considering the transmission errors can be derived as

$$S = \frac{P_s\left(1-P_{frag-error}\right)L}{P_s\left(1-P_{frag-error}\right)T_{success} + (1-P_s)T_{collision} + T_{idle} + P_s P_{frag-error} T_e} \quad (8)$$

Where L is the average packet payload size, $T_{success}$ is the average time that the channel is captured for a successful transmission with fragmentation, $T_{collision}$ is the average time that the channel is captured by stations which collide, P_s is the probability that a transmission is successful and T_e is the unsuccessful packet transmission time due to transmission errors.

Here, $T_{collision}$ and T_e are assumed to be same. L, $T_{success}$, $T_{collision}$ and *slottime* must be expressed in same units.

If the size of the fragment is L_{frag}, then the number of fragments X for a given packet of size L is L/L_{frag}. Now the additional overhead will be included to the fragmented frames to transmit the data but the packet error is reduced drastically.

$$T_{success} = DIFS + L + H + SIFS + ACK + L + \left(\frac{L+H}{L_{frag}} - 1\right)(H + 2SIFS + ACK) \quad (9)$$

$$T_{collison} = DIFS + SIFS + ACK + L_{frag} \quad (10)$$

$$P_{frag-error} = 1 - (1 - BER)^{L_{frag}} \quad (11)$$

In the above equations, H is the physical layer and MAC layer overhead and BER is the Bit Error Rate.

III.PACKET DELAY ANALYSIS

The delay performance of IEEE 802.11 protocol can be done by taking the retry limits of a data packet transmission into account. The packet drop probability is defined, as the probability that a packet is dropped when the retry limit is reached and it is equal to

$$p_{drop} = p^{m+1} \quad (12)$$

Since a packet is dropped if it encounters m+1 collisions. Let $E[T_{drop}]$ be the average number of slot times required for a packet to experience m+1 collision in the (0, 1…m) stages,

$$E[T_{drop}] = \frac{cw.(2^{m+1} - 1) + (m+1)}{2} \quad (13)$$

The average length of a slot time is

$$E[slot] = (1 - p_{tr})\sigma + p_{tr} \cdot p_s \cdot T_s + p_{tr} \cdot (1 - p_s) T_c \quad (14)$$

Finally, the average time to drop a packet is equal to $E[D_{drop}] = E[T_{drop}]E[slot]$ (15)

The average delay for a successfully transmitted packet is defined to be the time interval from the time the packet is at the head of its MAC queue ready to be transmitted, until an acknowledgement for this packet is received. If a packet is dropped because it has reached the specified retry limit, the delay time for this packet will not be included into the calculation of the average delay. The average packet delay $E[D]$, provided that this packet is not discarded, is given by

$$E[D] = E[X].E[slot] \quad (16)$$

Where $E[X]$ is the average number of slot times required for successfully transmitting a packet and is given by

$$E[X] = \frac{(1-2p).(cw+1) + p.cw.\left(1-(2p)^m\right)}{2.(1-2p).(1-p)} \quad (17)$$

IV. SIMULATION RESULTS

The simulation parameters used for analyzing the throughput and delay of IEEE 802.11b network.

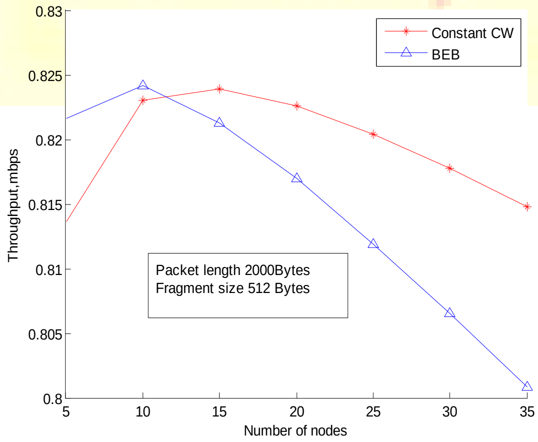

Fig.2 Number of Nodes versus Throughput

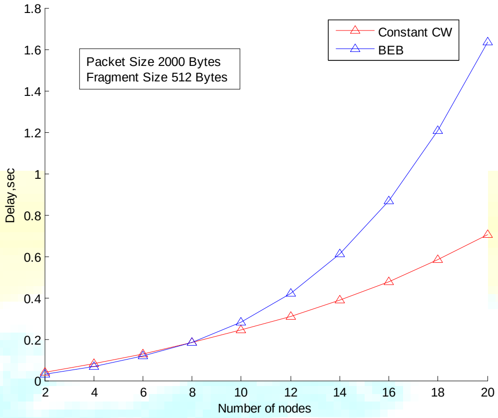

Fig.3 Number of Nodes versus DeLay

Figure2, Figure3, the number of stations are varied and use the packet size of 2000 bytes and fragment size of 512 bytes in Fig.2 and Fig.3. In this figures show that the number of nodes into the throughput and number of nodes into delay. The probability of collision increases with increase in number of contending nodes and hence the throughput decreases. But the throughput can be increased by selecting the proper contention window even the number of nodes increases. In this analyze the throughput and delay using two algorithms i.e., BEB and Constant contention window. The constant contention window get better throughput and less delay compare to the BEB scheme.

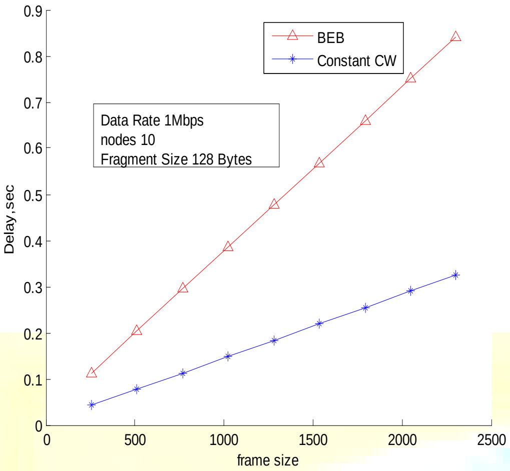

Fig.4 Frame Size versus DeLay

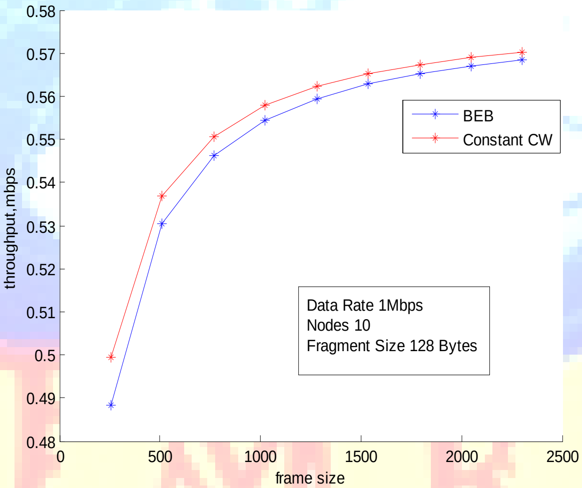

Fig.5 Frame Size versus Throughput

Fig. 4 and Fig. 5 plots the Frame size versus throughput and Frame size versus delay. Here, the bits are transmitted at 1 Mbps and the number of contending nodes is set at 10. The constant contention window is used and is set at 31. In this analyze the throughput and delay using two algorithms i.e., BEB and Constant contention window. The constant contentionwindow get better throughput and less delay compare to the BEB scheme.

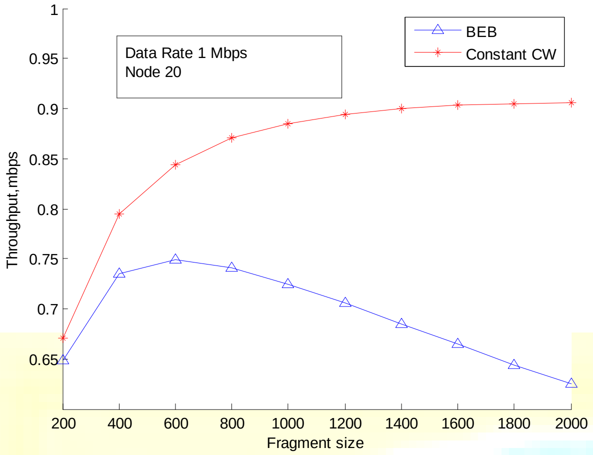

Fig.6 Fragment Size versus Throughput

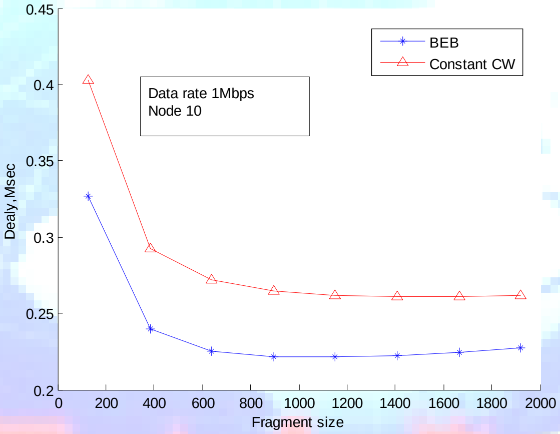

Fig.7 Fragment Size versus DeLay

Fig.6 and Fig.7 plots the Fragment size versus throughput and Fragment size versus delay. Here, the bits are transmitted at 1 Mbps and the number of contending nodes is set at 10. The constant contention window is used and is set at 31. The overhead for the smaller fragments is relatively large compared to larger fragments. But if the larger fragments are corrupted due to noisy channels, the entire fragment is to be retransmitted. It is observed that as the fragment size increases, the throughput decreases.

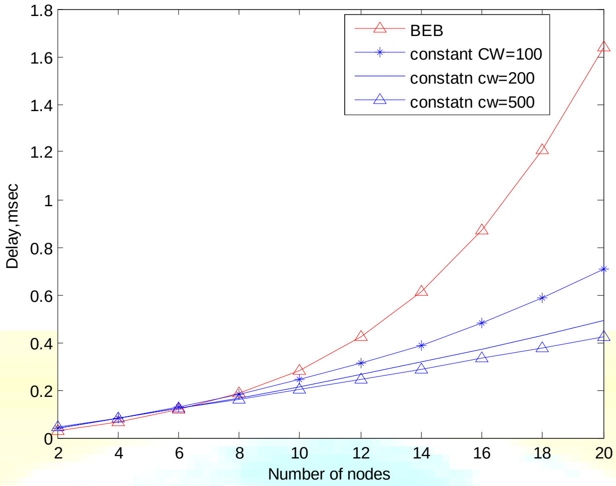

Figure 8 Number of nodes versus Delay

The packet delay analysis for various nodes using BEB and Constant contention window algorithms is plotted in Fig 8. The packet delay reduces by properly selecting contention window size in constant backoff algorithm. If the contention window is selected as 200, one can get the minimum packet delay which is very important.

V. CONCLUSION

In most applications fragmentation is used primarily to reduce the impact of interference and fading effects on performance. In case of errors, only the corrupted fragments are retransmitted instead of retransmitting the whole frame. In this thesis, throughput and delay analysis is carried out for different packet sizes at various fragmentation levels to evaluate the performance of IEEE 802.11 WLANs. The throughput and packet delay analysis is done using the two different algorithms i.e. constant contention window and binary exponential back-off algorithms.Simulation results shows that the packet delay increases and throughput decreases in BEB compared to Constant backoff algorithm. The optimal fragment size and optimal contention window are determined to achieve the maximum throughput for the specified BER.

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