Comparative Study of Back-off Algorithm in MAC Protocol IEEE 802.11

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Abstract: **In wireless communication environments, backoff is traditionally based on the IEEE binary exponential backoff (BEB). Using BEB results in a high delay in message transmission, collisions and ultimately wasting the limited available bandwidth. As each node has to obtain medium access before transmitting a message, in dense networks, the collision probability in the MAC layer becomes very high when a poor backoff algorithm is used. The Logarithmic algorithm proposes some improvements to the backoff algorithms that aim to efficiently use the channel and to reduce collisions. The algorithm under study is based on changing the incremental behavior of the backoff value. The Binary Exponential Backoff (BEB) is used by IEEE 802.11 Medium Access Control (MAC). This paper carries out a survey of the backoff algorithm, many researchers had done a lot of work on exponential back off but there are certain limitations in BEB which is overcome in logarithmic back off algorithm.**

Keywords: IEEE 802.11, Backoff algorithm, Ad Hoc networks, Medium access control, contention window and DCF.

I. INRODUCTION

IEEE-802.11 MAC protocol is the standard for wireless LAN.This MAC protocol adopts two media access methods, one is Distributed Coordination Function (DCF), and the other is Point Coordination Function (PCF). Among of them, the DCF is the fundamental access method for the 802.11 MAC, and widely used in WLAN and ad hoc networks.

IEEE 802.11 DCF protocol is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) with binary slotted exponential Backoff .Medium Access Control (MAC)protocols allow multiple users to share a common transmission channel, such as 802.11 wireless LAN and Ethernet. Collision occurs when multiple nodes send the messages at the same time. Backoff algorithm is a widely adopted collision resolution scheme in most MAC protocol. Many backoff algorithms have been developed in the literature [1].One example is the truncated binary exponential backoff scheme employed in Ethernet [2].the backoff delay increased by larger and larger amounts on each successive collision, up to finite number of retransmission attempts.

Many researchers have proposed the mechanism of channel sensing, or packet sensing to avoid collision. The sensing mechanisms typically rely on the transmitter and receiver performing a handshake prior to the transmission of the data packet [3]. More specifically, The Medium Access Collision Avoidance (MACA) method proposed by Karn [4] implements the handshake via a pair of Request-To-Send (RTS) and Clear-To-Send (CTS) messages. When a node has to send data to another, it first sends a short RTS packet to the destination. The receiver responds with a CTS packet [3]. On receipt of the CTS, the sender sends its queued data packet(s). All other nodes overhearing the CTS message will defer from sending out any packet until the predicted transmission period indicated in the CTS packet, is passed. Any node that overhears the RTS signal but not CTS is allowed to send out packets in a certain time the period as either the RTS/CTS handshake is not completed or it is out of range of receiver.

II. BACKOFF PROCEDURE

In the backoff procedure, the node randomly chooses a value according to the contention window, and initializes its backoff timer with this value. The backoff timer shall be decremented by one if the channel is idle for a slot time If the channel is sensed busy during a slot time, the backoff timer shall not decrement, and the backoff procedure will be resumed until the channel will be determined to be idle for a period of time. The node transmits its frame whenever the backoff timer reaches zero. At the first transmission attempt, the value of Contention Window (CW) shall take an initial value CWmin. CW is doubled after every unsuccessful transmitting until its value reaches CWmax, a predefined maximum value of CW. The initial value of backoff timer is an integer randomly selected from zero to CW.

The value specified for Minimum Contention Window is the upper limit (in milliseconds) of a range from which the initial random backoff wait time is determined. The first random number generated will be a number between 0 and the number specified here. If the first random backoff wait time expires before the data frame is sent, a retry counter is incremented and the random backoff value (window) is doubled. Doubling will continue until the size of the random backoff value reaches the number defined in the Maximum Contention Window.

Valid values for cwMin are 1, 3, 7, 15, 31, 63, 127, 255, 511, or 1023. The value for cwMin must be less than or equal to the value for cwMax.

III. OVERVIEW OF EBA

In distributed multiple access, a simple yet effective random backoff algorithm is widely used to avoid collisions. In particular, the binary exponential backoff algorithm [5] adjusts the contention window size dynamically in react to collision intensity. Such an algorithm is embedded in the IEEE 802.11 Distributed Coordination Function (DCF).DCF operates as follows (Figs.1-2). Before an attempt of data transmission is made, a station senses the channel to determine whether it is idle. If the medium Is sensed idle throughout a specified time interval, called the *distributed inter-frame space* (DIFS), the station is allowed to transmit. If the medium is sensed busy, the transmission is deferred until the ongoing transmission terminates. A slotted binary exponential backoff procedure takes place at this point: a random backoff interval value is uniformly chosen in [0;CW ¡ 1] and used to initialize the backoff timer, where CW is the current contention window size. The backoff timer keeps running as long as the channel is sensed idle, paused when data transmission (initiated by other stations) is in progress, and resumed when the channel is sensed idle again for more than DIFS.

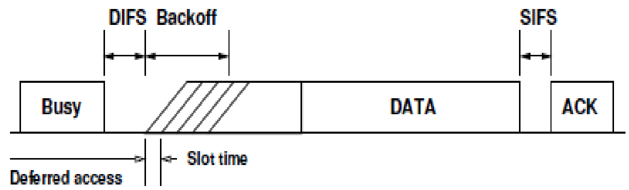

Fig. 1. IEEE 802.11 DCF without RTS-CTS.

The time immediately following an idle DIFS is slotted, with each slot equal to the time needed for any station to detect the transmission of a frame (in the IEEE 802.11 term, MAC Service Data Unit (MSDU)) from any other station. When the backoff timer expires, the station attempts to transmit a data frame at the beginning of next slot. Finally, if the data frame is successfully received, the receiver transmits an acknowledgment frame after a specified interval, called the *short inter-frame space* (SIFS), that is less than DIFS. If an acknowledgment is not received, the data frame is presumed to be lost, and a retransmission is scheduled. The value of CW is set to CWmin in the first transmission attempt, and is doubled at each retransmission up to a pre-determined value CWmax.Retransmissions for the same data frame can be made up to a pre-determined retry limit, L, times. Beyond that, the pending frame will be dropped. In the case that the floor acquisition RTS-CTS mechanism is used, the same procedure is conducted except that an RTS-CTS handshake operation precedes the DATA-ACK exchange (Fig. 2).

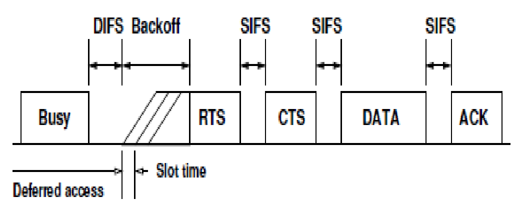

Fig. 2. IEEE 802.11 DCF with RTS-CTS.

A. PREVIOUS WORK ON BEB

The analysis uses a model that closely in terms of their effect on network performance as the offered load increases. Most of the works available, which are summarized below, focus on the stability of EB, and little work has been conducted on its performance analysis. Furthermore, these studies have produced contradictory results on the prove instability, others show stability under certain conditions. The mixed results are due to the differences in the analytical models, where simplified and/or modified models of the backoff algorithm are used, and in the definitions of stability used in the analysis.

For example, Aldous [6] proved that BEB is *unstable* for an infinite-node model (a simplified model) for any nonzero arrival rate, while Goodman *et al.* [7] showed using a modified finite-node model that BEB is *stable* for sufficiently small arrival rates. Most of the analytical and simulation studies on EB treat the backoff algorithm in the context of a specific network medium access control (MAC) protocol such as Ethernet [8],[9] or WLAN [10]. The characteristics of the specific protocol seem to have as much effect on the network performance results as the intrinsic behavior of EB. Thus, the results depend heavily on which MAC protocol is used in the study and it is not possible to understand the behavior of EB from the results.

There have been a number of work on performing the saturation throughput and delay analysis of IEEE 802.11DCF in single-hop wireless networks. They include [10],[11], [14], [12] and [13], etc. The most significant ones might be [10] done by Bianchi and [11] done by Cali *et al.*. The former uses a discrete Markov chain to model the backoff procedure performed by a tagged station, and the latter uses an iterative algorithm and takes a renewal process view of the channel activities. They motivate substantial subsequent analysis work such as [15],[16] and [17] etc.

IV. OVERVIEW OF LBA

In IEEE 802.11 MAC protocol, The BEB algorithm exponentially increases the size of contention window. BEB uses the following equation to increase the contention window size

BO = (Rand () MOD CW) * aSlotTime

The logarithmic backoff algorithm has used the logarithm of the current backoff time as the increment factor to calculate the next backoff. The following formula is used to give this result [18]

$$(BO)_{new} = (\log (BO)_{old})*(BO)_{old} * aSlotTime$$

The behavior of the new formula can be shown in fig.3.

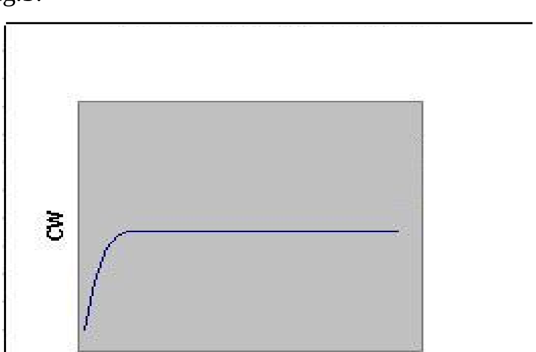

Fig.3: **CW increase in logarithmic algorithm**

LB algorithm is described as follows:

Step 0: CW = Int [CWmin * log(N)]
Step 1: while BO ≠ 0 do
For each time slot
If channel is idle then BO = BO – 1
Else BO = BO
IF BO=0 and channel is idle for more than DIFS then Send
Else
CW = Int[CW * log(N)
If (CW > CWmax) CW = CWmax
BO = Int[CW * Rand()]
Go to step 1

The values of CWmax and CWmin are determined by Physical layer norms of IEEE 802.11. The value of CW increases to Min(BO * log(N),CWmax) when a collision happens. On the contrary, the value of CW decreases to CWmin * log(N) after each successful interaction. In order to avoid “Channel Capture Effect”[19], the Rand() function which produces the random number between 0 and 1 is introduced.

V. COMPARATIVE STUDY OF EBA & LBA

1) BEB uses uniform random distribution to choose the backoff value, the logarithmic increments instead of exponential extension of window size to eliminate the effect of random number distribution.

2) Throughput (BEB) increases with the increase of traffic load until the maximum throughput is achieved. As traffic load is too large, mobile nodes can not compete effectively for the resources, so there are too many packets overstocked in queue of high-level, some data drops, and throughput (BEB) decreases rapidly with the increase of traffic load. Throughput (LB) increases with the increase of traffic load until the maximum throughput is achived, then becomes steady with the increase of traffic load.

Compared with BEB algorithm, the throughput of LB algorithm is increased.

3)In BEB, when a node loses in contention for channel access, there is a relatively high possibility that the next backoff timer will be double as the current value; this assigns the node larger probability to lose in the next contention against new arrivals and contention winners [20]. When using the logarithmic algorithm, the difference between the two backoff periods is smaller, and so the chance of losing the contention is not dramatically increased by the logarithmic algorithm.

4) Fairness of BEB algorithm and LB Algorithm is 1 when the number of nodes is less. FI increases with the increase of traffic load, when the number of nodes is more. Compared with BEB algorithm, the performance of fairness (LBA) is improved [21] .

Fairness=THmax/Thmin

Where THmax is maximum throughput and, Thmin is minimum throughput.

5) Channel access delay of BEB algorithm and LB algorithm is 0 when the number of nodes is less. As the traffic load is too large, mobile station cannot compete effectively for the resources when the number of nodes is more, so there are too many packets overstocked in queue, increasing waiting time for service leads to the increase of end-to-end delay. Compared with BEB algorithm, the performance of delay (LBA) is improved.

6) Logarithmic algorithm tends to accomplish better results with larger networks. Increasing the number of nodes over the network leads to less packet loss for the logarithmic algorithm.

VI. CONCLUSION

In this paper, we have studied a comparative analysis of backoff algorithms, after study we conclude that the exponent backoff has number of drawback and this drawback can be avoided by the logarithmic backoff algorithm. The performance of logarithmic backoff is better than exponential backoff algorithm in terms of backoff time distribution, throughput, value of contention window, fairness, channel access delay and packet loss.

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