Binary Exponential Increment Half Decrement Backoff Algorithm for IEEE802.11 Wireless LANs

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Abstract*- Backoff algorithm is a technique to reduce packet collisions and to improve throughput efficiency in wireless local area network (WLAN). In this research, we propose a new backoff algorithm which is named Binary Exponential Increment Half Decrement (BEIHD) backoff algorithm. Furthermore, we introduce a new discrete Markov chain model for modeling the performance analysis of wireless local area network. A new model is called the Fixed Backoff stages and Fixed Contention windows (FBFC) technique. In FBFC scheme, the accuracy of the transmission probability parameter is derived from step by step procedure using the global balance equation concept in steady state condition. The saturated throughput efficiency of all backoff algorithms is compared under the same Physical layer (PHY) parameters and Medium Access Control (MAC) scheme in IEEE802.11a/b/g standards. Our numerical results show that the throughput performance of BEIHD backoff algorithm is better than the Binary Exponential Backoff (BEB) algorithm. Moreover, the distinction of BEIHD backoff algorithm is near the realistic system, and it can be implemented without to modify hardware in physical layer.

***Keywords*-Backoff algorithm, BEB, BEIHD, FBFC, WLAN, IEEE802.11a/b/g**

I. INTRODUCTION

In previous researches, the references [4], [5] and [6] derived a simple discrete Markov chain model. Some time, this model is called Bianchi's model. From Bianchi's model, the transmission probability (τ) of Binary Exponential Backoff algorithm that depends on the backoff stages i ($i = 0, 1, 2 \ldots m$), the collision probability (P) and the contention window sizes (CW) is given by

$$\tau_{[Bianchi's\ model]} = \frac{2(1-2p)}{(1-2p)(CW+1)+pCW(1-(2p)^m)} \tag{1}$$

The transmission probability (τ) is the most importance parameter which is used to calculate the saturated throughput performance of the IEEE802.11 Distributed Coordination Function (DCF) for wireless local area network.

However, the previous researches derived the transmission probability from two-dimension discrete Markov chain model in the general from under unlimited backoff stages and unlimited contention window sizes. So, the key of this research is intended to improve the accuracy and realization of discrete Markov chain model by using the Fixed Backoff stages and Fixed Contention windows (FBFC) technique. Moreover, we propose a new backoff algorithm for improved saturation throughput efficiency of IEEE802.11 WLAN system.

This paper is organized as follow. In section II, we introduce the transmission probability of BEB algorithm which is derived from the Fixed Backoff stages and Fixed Contention windows technique. In section III, we propose a new backoff algorithm (BEIHD backoff algorithm) in the Fixed Backoff stages and Fixed Contention windows technique. In section IV, we describe the procedure of saturated throughput calculation. In section V, we give some numerical results. Finally, the conclusion is explained in section VI.

II. BEB ALGORITHM IN FBFC MODEL

In binary exponential backoff technique, the contention window sizes in backoff mode are uniformly chosen in the range from minimum contention window sizes (CW_{min}) to maximum contention window sizes (CW_{max}). A new discrete Markov chain model of binary exponential backoff algorithm in fixed backoff stage and fixed contention window sizes is shown in Fig. 2. The contention window sizes of BEB algorithm equals $2^i \times CW_{min}$ where i is the backoff stages or the retransmission. In this research, the backoff stage i can be increased up to 7 stages ($i = 0, 1, 2, 3 \ldots 7$). Thereby, the maximum contention window size is 1024 timeslots (0 to 1023), and the minimum contention window size is 8 timeslots (0 to 7). At the first transmission attempt of a contending station, the initial contention window size is equal to a CW_{min}. Afterward, the contention window sizes are decreased from slot by slot during the idle period is more than the Distributed Inter Frame Space (DIFS) time. Subsequently, the contention window sizes are counted down to zero, a contending station transmits a data packet. If the transmission fails or the collision happen, the contention window size is doubled

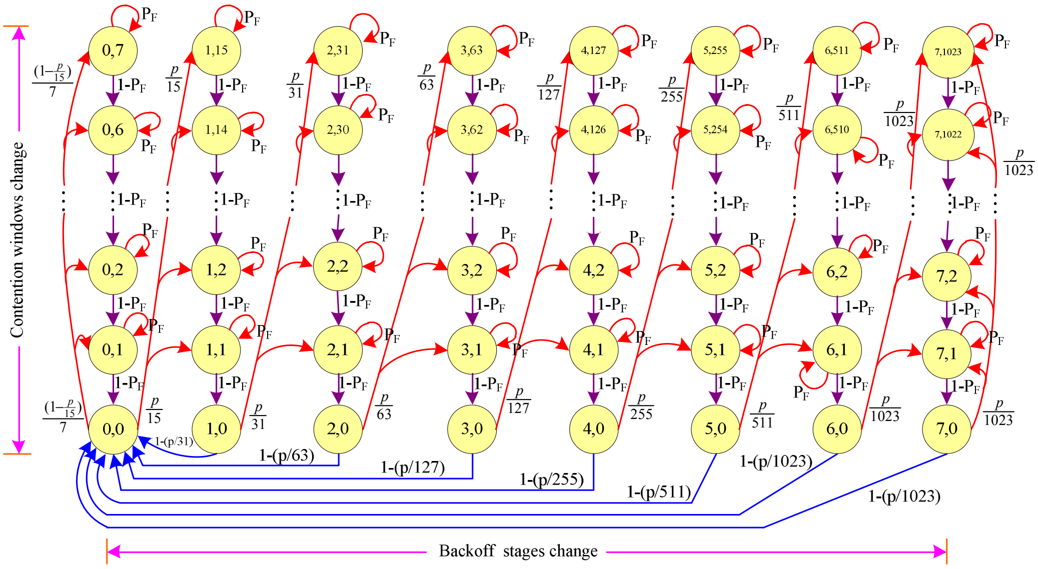

Fig. 2 Binary exponential backoff algorithm in fixed backoff stages and fixed contention window sizes (FBFC) technique (a new discrete Markov chain model)

to reach the CW_{max}. In FBFC model, the state probability of each backoff stages and contention window sizes is denoted $b_{i,k}$ where i is the backoff stage, and k is the contention window size. The backoff stage i vary from 0 to 7 stages and the contention window size k vary from 0 to 1023 timeslots. The P_F is the probability that a contending station stops its countdown process when the channel is sensed busy. P is the collision probability of a data packet to transmit through wireless channel. From Fig.2, we use the global balance equation concept to derive the transmission probability of BEB algorithm from step by step in fixed backoff stages and fixed contention windows scheme. This technique is the same concept to derive the transmission probability of BEIHD backoff algorithm that is detailed in the next section. In steady state condition, the transmission probability of the BEB algorithm (τ_{BEB}) can be derived and simplified as

$$\tau_{BEB} = \frac{1}{\left[1+B+BC+BCD+BCDE+BCDEF+BCDEFG+\left[\frac{H}{1-H}\right]BCDEFG\right]} \tag{2}$$

Where $B = \frac{p}{15}\sum_{L=1}^{15}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L$, $C = \frac{p}{31}\sum_{L=1}^{31}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L$

$D = \frac{p}{63}\sum_{L=1}^{63}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L$, $E = \frac{p}{127}\sum_{L=1}^{127}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L$

$F = \frac{p}{255}\sum_{L=1}^{255}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L$, $G = \frac{p}{511}\sum_{L=1}^{511}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L$

$H = \frac{p}{1023}\sum_{L=1}^{1023}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L$

III. BEIHD Backoff Algorithm in FBFC Model

This section, we propose a new backoff algorithm called the Binary Exponential Increment Half Decrement (BEIHD) backoff algorithm. In fixed backoff stages and fixed contention window sizes scheme, the BEIHD backoff algorithm is shown in Fig. 3. Significantly, the BEIHD backoff algorithm is differenced from the BEB algorithm when the transmission is successful. After a collision transmission, the contention window size is doubled of the current contention window sizes (BEI: Binary Exponential Increment) until the contention window reach to the maximum contention window sizes. Subsequent a successful transmission, the contention window sizes is not reset to the initial value (CW_{min}), but the contention window sizes of the BEIHD algorithm is set to the half contention window sizes of the previous backoff stage (HD: Half Decrement). For example, if the current backoff stages are 5, the range of contention window size is 0 to 255 timeslots. Posterior a successful transmission, the new backoff stage is set to go back to 4, and a new contention window size is set to the half range of a new backoff stage. In this case, the new contention window size is 63 timeslots. Similarly, we use the global balance equation concept to derive the transmission probability (τ). In fixed backoff stages and fixed contention window sizes scheme, $b_{i,k}$ is the state probability of backoff stages i, and contention window size k timeslots.

In fixed backoff stages and fixed contention window sizes technique, a data packet transmission occurs when the contention windows are counted down to zero. By imposing the normalization condition, the transmission probability of the Binary Exponential Increment Half Decrement backoff algorithm (τ_{BEIHD}) is given by

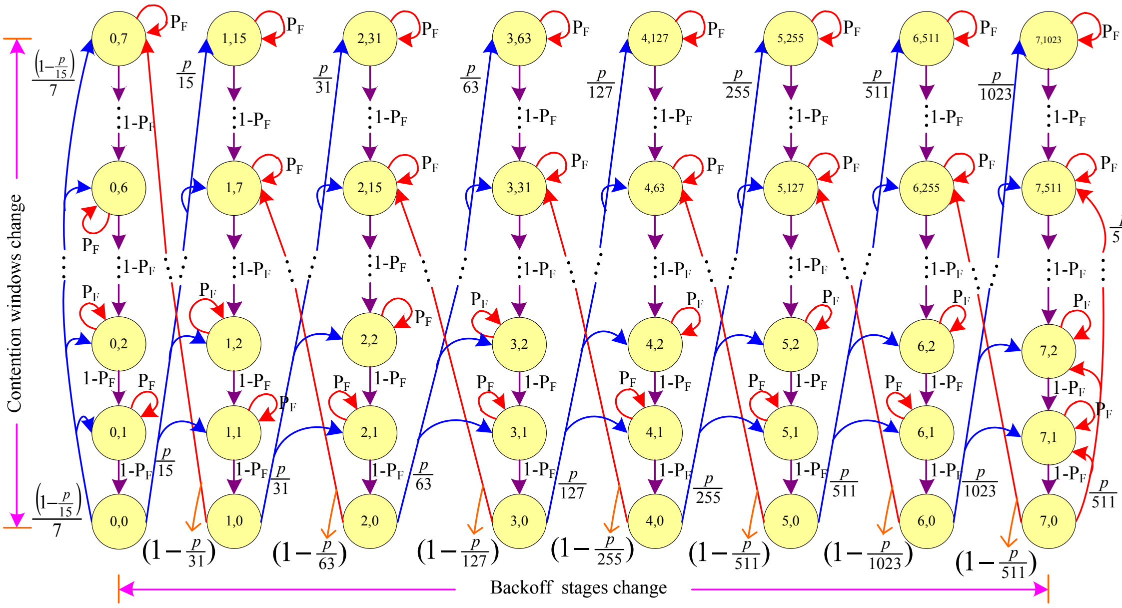

Fig. 3 Binary Exponential Increment Half Decrement backoff algorithm in fixed backoff stages and fixed contention window sizes technique (A new discrete Markov chain model and a new backoff algorithm)

$$\tau_{BEIHD} = \sum_{i=0}^{7} b_{i,0} = b_{0,0} + b_{1,0} + b_{2,0} + b_{3,0} + b_{4,0} + b_{5,0} + b_{6,0} + b_{7,0} \quad (3)$$

Where

$$b_{0,0} = \left\{ \frac{7\times 15\left(1-\frac{p}{31}\right)}{(15+6p)}\left[\frac{(1-P_F)}{(1-2P_F)}\right] \Bigg/ \left[1-\frac{15\left(1-\frac{p}{15}\right)}{(15+6p)}\sum_{L=1}^{7}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L\right] \right\} b_{1,0},$$

$$b_{1,0} = \frac{p}{15}\sum_{L=1}^{7}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{0,0} + \frac{p}{15}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^7 \sum_{L=1}^{8}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{0,0} + \left(1-\frac{p}{63}\right)\left[\frac{(1-P_F)}{(1-2P_F)}\right]^7 b_{2,0},$$

$$b_{2,0} = \frac{p}{31}\sum_{L=1}^{15}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{1,0} + \frac{p}{31}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{15} \sum_{L=1}^{16}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{1,0} + \left(1-\frac{p}{127}\right)\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{15} b_{3,0}$$

$$b_{3,0} = \frac{p}{63}\sum_{L=1}^{31}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{2,0} + \frac{p}{63}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{31} \sum_{L=1}^{32}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{2,0} + \left(1-\frac{p}{255}\right)\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{31} b_{4,0}$$

$$b_{4,0} = \frac{p}{127}\sum_{L=1}^{63}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{3,0} + \frac{p}{127}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{63} \sum_{L=1}^{64}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{3,0} + \left(1-\frac{p}{511}\right)\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{63} b_{5,0}$$

$$b_{5,0} = \frac{p}{255}\sum_{L=1}^{127}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{4,0} + \frac{p}{255}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{127} \sum_{L=1}^{128}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{4,0} + \left(1-\frac{p}{1023}\right)\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{127} b_{6,0}$$

$$b_{6,0} = \frac{p}{511}\sum_{L=1}^{255}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{5,0} + \frac{p}{511}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{255} \sum_{L=1}^{256}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{5,0} + \left(1-\frac{p}{511}\right)\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{255} b_{7,0}$$

$$b_{7,0} = \frac{p}{1023}\sum_{L=1}^{511}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{6,0} + \frac{p}{1023}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{511} \sum_{L=1}^{512}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L b_{6,0} + \frac{p}{511}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{511} b_{7,0}$$

Finally, the transmission probability of BEIHD backoff algorithm is simplified

$$\tau_{BEIHD} = 1 \Bigg/ \left[\begin{array}{l} 1+(A_1+A_2S)+S+\frac{(H_2+C_2R)}{H_1}+R+ \\ (J_1+QJ_2)+Q+\frac{K_1G_1}{(1-G_2-G_1K_2)} \end{array}\right] \quad (4)$$

Where

$$A_1 = \frac{p}{15}\sum_{L=1}^{7}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L + \frac{p}{15}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^7 \sum_{L=1}^{8}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L$$

$$A_2 = \left(1-\frac{p}{63}\right)\left[\frac{(1-P_F)}{(1-2P_F)}\right]^7, \quad S = \left[\frac{A_1B_1}{(1-A_2B_1)} + \frac{B_2(H_2+C_2R)}{(1-A_2B_1)H_1}\right]$$

$$B_1 = \frac{p}{31}\sum_{L=1}^{15}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L + \frac{p}{31}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{15} \sum_{L=1}^{16}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L$$

$$B_2 = \left(1-\frac{p}{127}\right)\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{15}, \quad H_1 = \left[\frac{(1-A_2B_1)-B_2C_1}{(1-A_2B_1)}\right]$$

$$C_1 = \frac{p}{63}\sum_{L=1}^{31}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L + \frac{p}{63}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{31} \sum_{L=1}^{32}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^L$$

$$C_2=\left(1-\frac{p}{255}\right)\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{31},\quad H_2=\left[\frac{A_1B_1C_1}{(1-A_2B_1)}\right]$$

$$D_1=\frac{p}{127}\sum_{L=1}^{63}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{L}+\frac{p}{127}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{63}\sum_{L=1}^{64}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{L}$$

$$D_2=\left(1-\frac{p}{511}\right)\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{63},\quad R=(I_1+I_2J_1+QJ_2I_2)$$

$$E_1=\frac{p}{255}\sum_{L=1}^{127}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{L}+\frac{p}{255}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{127}\sum_{L=1}^{128}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{L}$$

$$E_2=\left(1-\frac{p}{1023}\right)\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{127},\quad I_1=\left[\frac{D_1H_2}{(H_1-D_1C_2)}\right]$$

$$F_1=\frac{p}{511}\sum_{L=1}^{255}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{L}+\frac{p}{511}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{255}\sum_{L=1}^{256}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{L}$$

$$F_2=\left(1-\frac{p}{511}\right)\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{255},\quad I_2=\left[\frac{D_2H_1}{(H_1-D_1C_2)}\right]$$

$$G_1=\frac{p}{1023}\sum_{L=1}^{511}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{L}+\frac{p}{1023}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{511}\sum_{L=1}^{512}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{L}$$

$$G_2=\frac{p}{511}\left[\frac{(1-P_F)}{(1-2P_F)}\right]^{511},\quad J_1=\frac{E_1I_1}{(1-E_2I_2)},\quad J_2=\frac{E_2}{(1-E_1I_2)}$$

$$K_1=\frac{F_1J_1}{(1-F_1J_2)},\quad K_2=\frac{F_2}{(1-F_1J_2)},\quad Q=\left[K_1+\frac{K_1K_2G_1}{(1-G_2-G_1K_2)}\right]$$

IV. SATURATED THROUGHPUT CALCULATION

In distributed coordination function, the data packets transmission in WLAN system uses the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol. This medium access technique has two access categories which are the CSMA/CA in Basic mode and Request-to-send Clear-to-Send (RTS CTS) mode. The CSMA/CA RTS CTS scheme is used to solve the hidden stations problem. The CSMA/CA in RTS CTS mode is shown in Fig. 4.

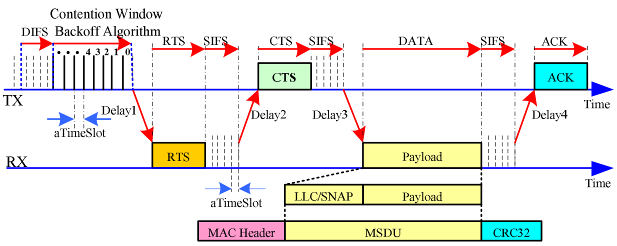

Fig. 4 Carrier sense multiple access with collision avoidance and request-to-send clear-to-send protocol

In Basic and RTS CTS mode, we calculate the saturation throughput in the same procedures. Only, the CSMA/CA in Basic mode doesn't have the Request-to-Send and Clear-to-Send control frames. Therefore, a packet transmission time in both mechanisms is different. In physical layer parameter of CSMA/CA protocol, we use the same values in [7]. The average of successful transmission time is T_S, and the average of collision time is T_C. In Basic and RTS CTS mechanisms, The T_S and T_C are calculated from

$$T_{S[CSMA/CA\ Basic]}=T_{DIFS}+T_{MSDU}+T_{SIFS}+2T_{delay}+T_{ACK} \tag{5}$$

$$T_{C[CSMA/CA\ Basic]}=T_{DIFS}+T_{delay} \tag{6}$$

$$T_{S[CSMA/CA\ RTS\ CTS]}=T_{RTS}+3T_{SIFS}+4T_{delay}+T_{CTS}+T_{MSDU}+T_{ACK}+T_{DIFS} \tag{7}$$

$$T_{C[CSMA/CA\ RTS\ CTS]}=T_{DIFS}+T_{RTS}+T_{delay} \tag{8}$$

$$T_{MSDU}=\frac{[PHY\ header\ in\ bytes]+[MAC\ header\ in\ bytes]+[PAYLOAD\ in\ bytes]\times 8}{Data\quad rate\,[Mbps]} \tag{9}$$

In this paper, the data rate of IEEE802.11b, IEEE802.11a and IEEE802.11g standards are fixed at 11 Mbps, 24 Mbps and 54 Mbps, respectively. Same in [4], the saturation throughput is calculated from

$$Throughput=S=\frac{Number\ of\ bytes\ sent}{Duration\ of\ the\ transmission}$$

$$S=\frac{P_SP_{tr}(MSDU\times 8)}{(1-P_{tr})T_{aTimeSlot}+P_SP_{tr}T_S+P_{tr}P_CT_C} \tag{10}$$

$$P_{tr}=1-(1-\tau_{[Bianchi's\ model]})^n \tag{11}$$

$$P_S=\frac{n\tau_{[Bianchi's\ model]}(1-\tau_{[Bianchi's\ model]})^{n-1}}{1-(1-\tau_{[Bianchi's\ model]})^n} \tag{12}$$

$$P_C=1-P_S \tag{13}$$

where n = the number of contending station

Similarly, the saturation throughput of BEB and BEIHD backoff algorithms in FBFC technique is calculated from

$$S_{BEB}=\frac{P_{S[BEB]}P_{tr[BEB]}(MSDU\times 8)}{(1-P_{tr[BEB]})T_{aTimeSlot}+P_{S[BEB]}P_{tr[BEB]}T_S+P_{tr[BEB]}P_{C[BEB]}T_C} \tag{14}$$

$$P_{tr[BEB]}=1-(1-\tau_{BEB})^n \tag{15}$$

$$P_{S[BEB]}=\frac{n\tau_{BEB}(1-\tau_{BEB})^{n-1}}{1-(1-\tau_{BEB})^n} \tag{16}$$

$$P_{C[BEB]}=1-P_{S[BEB]} \tag{17}$$

$$S_{BEIHD}=\frac{P_{S[BEIHD]}P_{tr[BEIHD]}(MSDU\times 8)}{\left[\begin{array}{l}(1-P_{tr[BEIHD]})T_{aTimeSlot}+P_{S[BEIHD]}P_{tr[BEIHD]}T_S+\\ P_{tr[BEIHD]}P_{C[BEIHD]}T_C\end{array}\right]} \tag{18}$$

$$P_{tr[BEIHD]}=1-(1-\tau_{BEIHD})^n \tag{19}$$

$$P_{S[BEIHD]}=\frac{n\tau_{BEIHD}(1-\tau_{BEIHD})^{n-1}}{1-(1-\tau_{BEIHD})^n} \tag{20}$$

$$P_{C[BEIHD]}=1-P_{S[BEIHD]} \tag{21}$$

These parameters are used to calculate the saturation throughput of CSMA/CA in IEEE802.11a/b/g standards which are described in Table 1, [1] [2] [3] and [7]. We use the computer simulation tool in [8] to calculate the saturation throughput. In simulation program, we compare the performance of all backoff algorithms under the same physical layer parameters and medium access control technique.

TABLE I TRANSMISSION TIMES IN CSMA/CA PROTOCOL

Periods	IEEE802.11 standards		
	801.11a	802.11b	802.11g
T_{SIFS}	16 µs	10 µs	10 µs
T_{DIFS}	34 µs	50 µs	28 µs
$T_{aTimeSlot}$	9 µs	20 µs	9 µs
T_{Delay}	1 µs	1 µs	1 µs
T_{RTS} OFDM 24Mbps	28 µs	-	34 µs
T_{CTS} OFDM 24Mbps	28 µs	-	32 µs
T_{ACK} OFDM 24Mbps	28 µs	-	32 µs
T_{RTS} OFDM 54Mbps	24 µs	-	30 µs
T_{CTS} OFDM 54Mbps	24 µs	-	30 µs
T_{ACK} OFDM 54Mbps	24 µs	-	30 µs
T_{RTS} HR 11 Mbps	-	352 µs	-
T_{CTS} HR 11 Mbps	-	403 µs	-
T_{ACK} HR 11 Mbps	-	403 µs	-

Limitations of this research, we assume that the channel is ideal and in saturated condition, channel is ignored the hidden stations and capture effects, the collision occurs when the WLAN channel has more than one contending stations to transmit a packet in a same aTimeSlot, the collision probability is constant and independent from the collision in the past, all data packets are the same sizes and the transmission of a data frame occurs when the contention window sizes are counted down to zero.

An algorithm 1 is used to calculate the saturated throughput of all backoff algorithms in Bianchi's model and FBFC model.

Algorithm 1.

Begin

Step 1: Fixed parameters P = 0.05, P_F = 0.05, MSDU = 1024 bytes, n = 1, 2, 3, … , 40 and CW = 8, 64, 128 and 1024 aTimeSlots, m = 7

Step 2: Calculate the T_S and T_c of CSMA/CA Basic mode by applying equation (5) and (6)

Step 3: Calculate the T_S and T_c of CSMA/CA *RTS CTS* mode by applying equation (7) and (8)

Step 4: Calculate the $\tau_{(\text{Bianchi's model})}$ of BEB algorithm by applying equation (1)

Step 5: Calculate the τ_{BEB} and τ_{BEIHD} in FBFC model by applying equation (2) and (4)

Step 6: Calculate the P_{tr} of *BEB* algorithm in Bianchi's model by applying equation (11)

Step 7: Calculate the $P_{tr[\text{BEB}]}$ and $P_{tr[\text{BEIHD}]}$ in FBFC model by applying equation (15) and (19)

Step 8: Calculate the P_S of BEB algorithm in Bianchi's model by applying equation (12)

Step 9: Calculate the $P_{S[\text{BEB}]}$ and $P_{S[\text{BEIHD}]}$ in FBFC model by applying equation (16) and (20)

Step 10: Calculate the P_C of BEB algorithm in Bianchi's model by applying equation (13)

Step 11: Calculate the $P_{C[\text{BEB}]}$ and $P_{C[\text{BEIHD}]}$ in FBFC model by applying equation (17) and (21)

Step12: Calculate the saturated throughput of BEB algorithm in Bianchi's model, the saturated throughput of BEB and BEIHD backoff algorithm in FBFC model by applying equation (10), (14) and (18)

End.

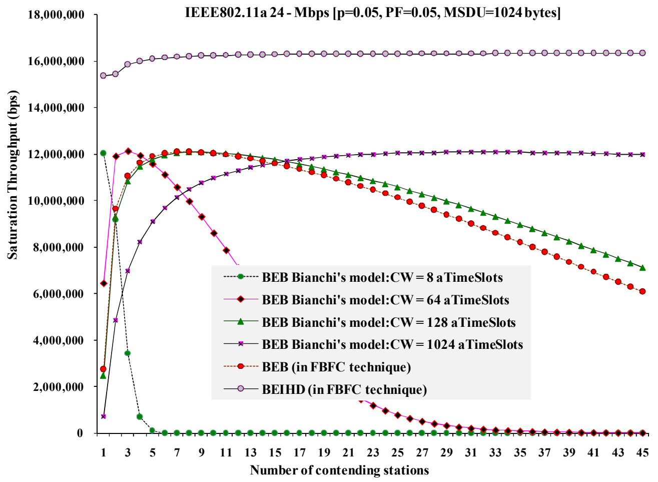

Fig. 5 Saturation throughput of BEB and BEIHD backoff algorithms in IEEE802.11a standard based on RTS CTS mode

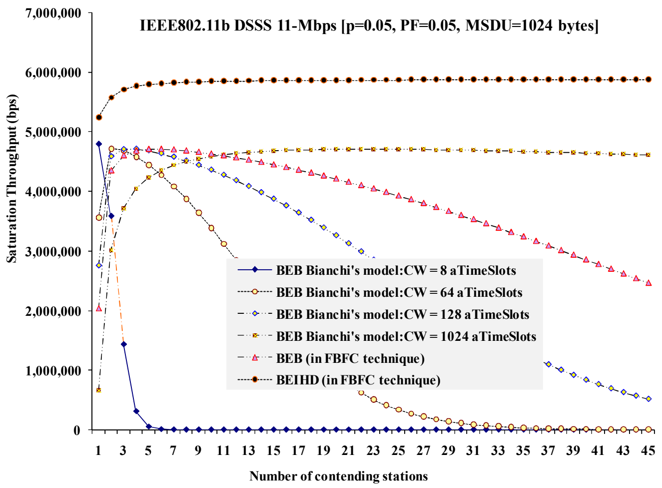

Fig. 6 Saturation throughput of BEB and BEIHD backoff algorithms in IEEE802.11b standard based on Basic mode

V. NUMERICAL RESULTS

In this section, we compare the numerical results of proposed backoff algorithm in term of saturation throughput between Bianchi's model and FBFC model. Firstly, Fig. 5 shows the saturated throughput performance in IEEE802.11a standard in case of RTS CTS scheme. From the result, we can see that the throughput of BEB algorithm in FBFC model is higher than the Bianchi's model when the contention window sizes are 8, and 64 timeslots. On the contrary, when the contention window sizes are 128 and 1024 timeslots, the saturated throughput of BEB algorithm in Bianchi's model is better than the throughput of BEB algorithm in FBFC model.

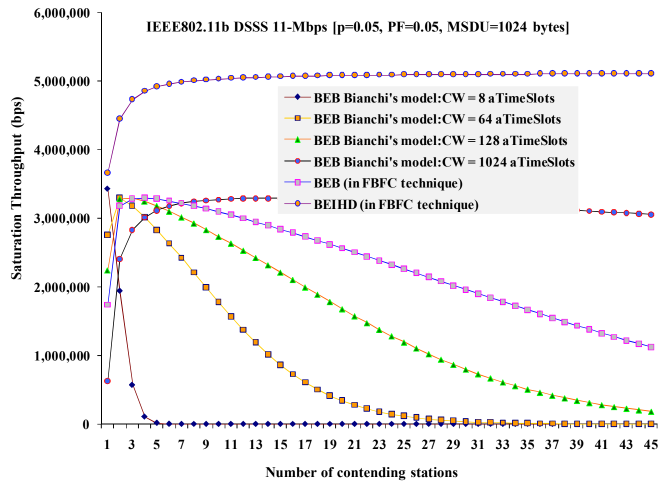

Fig.7 Saturation throughput of BEB and BEIHD backoff algorithms in IEEE802.11b standard based on RTS CTS mode

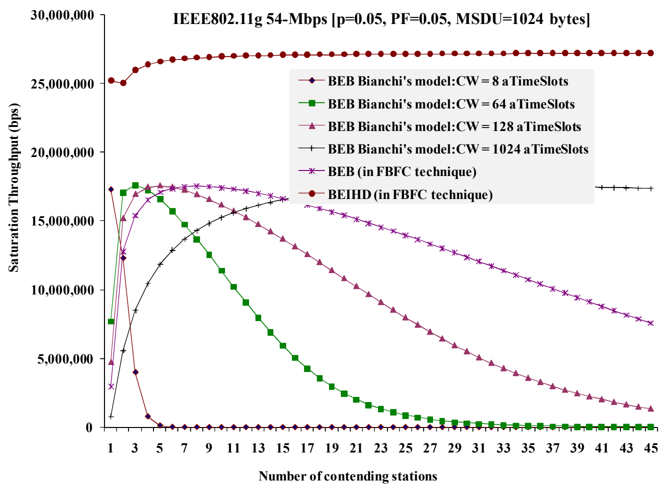

Fig. 8 Saturation throughput of BEB and BEIHD backoff algorithms in IEEE802.11g standard based on RTS CTS mode

Afterward, we compare only the saturated throughput between BEB algorithm and BEIHD backoff algorithm. The results illustrate that the throughput performance of the BEIHD backoff algorithm is higher than BEB algorithm although the number of contending stations is increased.

Fig. 6 and Fig. 7 compare the saturation throughput of BEB and BEIHD backoff algorithms in IEEE802.11b standard of the CSMA/CA protocol based on Basic and RTS CTS mode.

Fig. 8 shows the saturated throughput comparison of BEB and BEIHD backoff algorithms in IEEE802.11g standard.

Dramatically, when the contention window sizes are 8, 64 and 128 timeslots, the throughput of Bianchi's model seem to reduce quickly, but the throughput of FBFC model seem to reduce slowly. At the same range of contention window size, we can conclude that the saturation throughput of FBFC model is the average value of Bianchi's model. However, the results in Fig. 6, Fig. 7 and Fig. 8 guarantee that the throughput efficiency of BEIHD backoff algorithm is appropriate than the BEB algorithm in distributed coordination function for wireless local area networks.

VI. Conclusions

In this research, we have proposed a new discrete Markov chain model to evaluate the performance of WLAN system under saturated condition. A proposed model is called the FBFC scheme. Furthermore, we have introduced a new backoff algorithm which is named the Binary Exponential Increment Half Decrement (BEIHD) backoff algorithm. The numerical results have explained that the saturation throughput of BEIHD backoff algorithm is better than BEB algorithm. Also, the performance of BEIHD backoff algorithm is stable than BEB algorithm when the contending stations are increased. The distinction of BEIHD backoff algorithm is low complexity, and it can be implemented without to modify hardware in physical layer of IEEE802.11 WLAN standards.

In future work, we will evaluate the performance of BEIHD backoff algorithm under non-saturated WLAN channel conditions. We will investigate and design the optimum backoff algorithm for wireless local area networks as well.

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