A Oneself Adjusts Backoff Mechanism for Channel Access in IEEE 802.11 DCF WLAN

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***Abstract*—In recent years, Wireless Local Networks (WLANs) are becoming more and more popular. The IEEE 802.11 protocol is the one of the most deployed wireless access technologies. In order to minimize the collision probability due to multiple simultaneous transmissions, all stations compete for the wireless channel with a contention resolution method, namely Binary Exponential Backoff (BEB). In the BEB scheme, the contention window (CW) is double every time a station experiences transmission collision and decreased to its minimum value after a successful transmission. However, the performance degradation will be resulted from the aggressive reduction in the CW size. Accordingly, Exponential Increase Exponential Decrease (EIED) is proposed to suggest a slower reduction in a backoff period after a successful transmission. Actually, the variation of CW causes the unsteady system performance. In this paper, we proposed a Oneself Adjusts Backoff (OAB) mechanism to improve system performance over contention-based Distributed Coordination Function (DCF) WLANs. In the OAB, the variation of CW state will be kept based on the number of the consecutive collision or successful transmission. The numerical results show that the OAB mechanism provides a better system throughput and collision rate than the related backoff schemes.**

Keywords- BEB; DCF; Backoff

I. INTRODUCTION

In recent years, wireless local area network (WLAN) technology has been widely used due to startling developments of mobile technology. The IEEE 802.11 [1] standard provides both Medium Access Control (MAC) layer and the physical (PHY) layer specification for WLAN. IEEE 802.11 MAC has defined two medium access coordination functions: the contention-based Distributed Coordination Function (DCF) and the contention-free based Point Coordination Function (PCF). Every IEEE 802.11 station should support DCF mode. Unlike DCF, the implementation of PCF is optional in the standard. In this paper, we limit our investigation to the DCF and corresponding enhanced schemes.

Every IEEE 802.11 station should implement DCF mode, which is based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol. Before transmitting packets, the wireless node must detect the state of examining the wireless channel first. When the wireless channel is in the idle state, the wireless node will start the transmission. On the contrary, when the wireless channel is in a busy state, the wireless node will select a waiting time at random from the contention window, and then continue detecting the state of examining the wireless channel. When the state of the wireless channel is sensed idle, then the node will carry on waiting time and decrease progressively. When decreasing progressively as zero, the wireless node can start the transmission. When two or more wireless nodes decrease to zero at the same time, the transmission packets of wireless nodes will collide. Accordingly, in order to reduce the collision rate, IEEE 802.11 adopts the BEB (Binary Exponential Backoff) algorithm. In the BEB algorithm, the wireless node selects a backoff time to count backwards at random from the competition window. When the time of counting backwards is zero, the wireless node will start transmission. If the transmission is successful, the contention window will be set up into a minimum value (Minimum Contention Window, CW_{min}); if the collision is happened, the contention window will be double. The shortcoming of the BEB algorithm is that the collision rate will increase because the rapidly reset to minimum value of the contention window.

In relevant research, in order to prevent the frequent collision, in [2] [3] authors proposed the EIED (Exponential Increase Exponential Decrease) algorithm. When the wireless node transmits successfully, the contention window will be reduced to half. The EIED will provide better performance than DCF when the number of wireless node increases. EIED provides significant performance improvement without additional complexity. But, EIED algorithm changes the size of contention window rapidly, which causes systematic instability of the network performance. Accordingly, the LILD (Linear Increase Linear Decrease) algorithm was proposed. In the LILD, while succeeding in transmitting, the contention window size is reduced by one CW_{min}. On the contrary, when collision is taking place, the contention window size is increased by one CW_{min}. The LILD decreases variation of the contention window.

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In previous research [5] [6] [7] [8], the size of adjusting contention window is the topic influencing the wireless network system to be with very important efficiency. In the wireless network node of the contention, the large contention window can reduce the collision probability; at the same time, the transmission delay will increase. On the contrary, the small contention window size decreases the transmission waiting time; but it also results higher collision probability. In order to improve the efficiency of wireless transmission, this paper proposes a Oneself Adjusts Backoff algorithm (Oneself Adjusts Backoff, OAB). The OAB mechanism changes the contention window size based on the continuous successful transmission of collision, which is different from the traditional channel competition mechanism. The OAB mechanism makes the system in a stable state when the number of wireless nodes is in steady. In the OAB mechanism, the competition state of the channel will stay in the proper size of contention window and achieve the system in a stable state.

The structure of this paper is arranged as follows: section two recommends relevant research DCF, EIED and LILD. Section three recommends our proposed OAB mechanism. Section four discusses the simulation results. Finally, we give a conclusion and future work of this paper.

II. RELATED WORKS

A. IEEE 802.11 DCF

In the mechanism of DCF, the carrier sense activity consists in listening to the channel before transmitting: If the channel is found to be idle for a time interval greater than the Distributed Inter-Frame Space (DIFS) period, the station transmits directly, otherwise the station differs its transmission time until the ongoing transmission terminates. When the channel become idle again for a DIFS, the stations enters the collision avoidance phase by selecting a random interval of time slots called backoff interval that is used to initialize a backoff timer. But get the right to use of the wireless channel in other work stations first. While detecting and examining to the wireless channel to change into busily, freeze and backoff the counter first. When the wireless channel is transferred to again idly, and passed DIFS time, continued the unfinished reciprocal just now again. Over until counting backwards, could obtain the right of transmission and begin to transmit the package.

As shown in Fig. 1, DCF adopts an exponential backoff scheme called binary exponential backoff (BEB) mechanism. At each frame transmission, the backoff slot time is uniformly chosen in the range from 0 to *w-1*. The value *w* is called contention window (CW), and the size of CW is based on the number of transmissions failed for the frame. At the first transmission attempt, *w* is set equal to a value called minimum contention window (CW_{min}). After each unsuccessful transmission, the contention window is doubled, and up to a maximum value $CW_{max}=2^m x CW_{min}$. The values of the standard are PHY-specific and are summarized in Table I. The backoff time counter is decremented as long as the channel is sensed idle and "frozen" when a transmission is detected on the channel, and reactivated when the channel is sensed idle again for more than a DIFS. The mobile station transmits once the backoff time reaches zero.

TABLE I. DIFFERENT SPECS OF THREE PHY SPECIFIED BY THE IEEE 802.11 STANDARD.

PHY	CW_{min}	CW_{max}
FHSS	16	1024
DSSS	32	1024
IR	64	1024

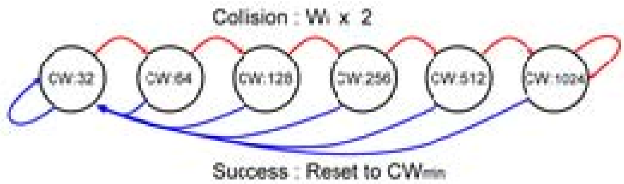

Figure 1. DCF algorithms of Markov Chain Model.

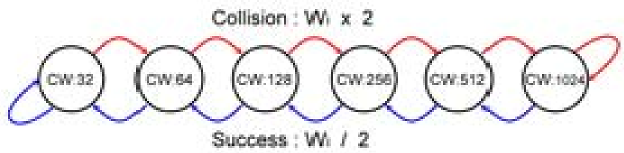

Figure 2. EIED algorithms of Markov Chain Model.

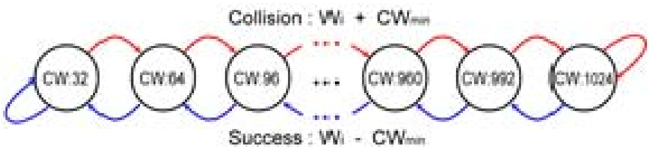

Figure 3. LILD algorithms of Markov Chain Model.

B. EIED algorithm

At present, there are several algorithm making an amendment based on BEB [2] [3] [5] [6]. The most initial state (CW_{max}) that get from final state (CW_{min})，The carriage return immediately, too heavy can increase probability of collision to assert change. EIED algorithm to direct against this question, revise for in after being successful, slow reduction of contention window size. In EIED, mainly increase or reduce the window by way of exponential. The Fig 2 is the behavior that EIED algorithm contention window. When transmitting successfully, the contention window is half at present $W = W_{i-1}/2$; On the contrary, when transmitting failing. It is the same to algorithm with DCF, the contention window is by increasing doubly $W = W_{i-1} \times 2$.

C. LILD algorithm

It is that enhanced MILD performs algorithm that LILD performs algorithm [9]. Different from EIED that the index changes and perform algorithm, LILD performs algorithm and uses the linear way to adjust for the contention window of the slow change, Fig. 3 is that LILD performs the behavior of the competition window in algorithm, CW_{min} and CW_{max} are set as 32 and 1024 in advance. When transmitting successfully, the contention window is decreased by CW_{min} ($W_i=W_{i-1}-CW_{min}$)

until to CW_{min}. When transmitting failing, the contention window is increased by CW_{min} ($W_i=W_{i-1}+CW_{min}$) until to CW_{max}.

III. Oneself Adjusts BACKOFF ALGORITHM (OAB)

A. *Oneself Adjusts Backoff*

In the Oneself Adjusts Backoff algorithm mechanism. Because collide in succession, size of contention window will fall back counter the environment of the network change at present and then. The low colliding rate of transmission, mean quantity of the work station is actually few.

Comparatively speaking, should set up the less contention window. On the contrary, if there is very high colliding rate of continuous transmission, show there are many wireless nodes in the competition in this wireless channel. That should set up the larger competition window, happen in order to reduce to collide. According to the explanation of the chapter 2, we can learn EIED and LILD perform algorithm, though carry on efficiency to improve to different networks load, a method does not accord with the state of high load or low load at the same time. So a thesis proposes to this topic one can adapt to the algorithm of different networks load. Different from traditional channel competition mechanism, change the competition state of the channel continuously because of transmitting success or failure, cause the instability of the network system. OAB algorithm the way in which the stable state transfers, when the network is in low load, the wireless node will stay at the little contention window, on the contrary, when changing greatly in load, the wireless node will let the contention window rise to the suitable size of contention window. Change of the competition state of the channel among them, the difference which transmits success or failure happens in the node of the network, will just take place while reaching the critical value. So the competition state of the channel, will stay in the proper size of contention window, will achieve the state of the stable system and purpose to improve efficiency.

B. *algorithm*

Table II recommends the Oneself Adjusts by exponential type mechanism of algorithm. It is zero to make the state change and count at the beginning (State Change Counter , SCC). While regarding as the work and conveying, succeed the number of times will add 1 (success_counter). But must enable succeeding and deduct and fail the number of times and is greater than the state and change counter value in number of times, can let contention window size shorten to original half, make the state change and count to reduce 1 just. On the contrary, when colliding, collide the number of times (collision_counter) add 1, but must enable colliding and deduct and fail the number of times and is greater than the state changing value in number of times, can just let the size of contention be increased for two fold, make the state change and count plus 1. Finally, no matter succeed in shortening the contention window or failing and increasing the contention window, the situation that state change, must make number of times of succeeding with fail number of times return zero, enter the next state.

TABLE II. ONESELF ADJUSTS BACKOFF ALGORITHMS.

```
Initial
State Change Counter (SCC) = 0
If (success)
{success_counter + 1
      If ( success_counter – collision_counter ) > SCC
         {Wi = Wi-1 / 2
         SCC – 1
         }
}
else (collision)
{collision _counter + 1
   If ( collision_counter –success_counter) > SCC
          {Wi = Wi-1 x 2
          SCC + 1
          }
}
When the state change occurs
                 success_counter = 0
                collision _counter = 0
```

C. *mechanism*

The Fig. 4 is the Oneself Adjusts to transfer the exponential type sketch map of the mechanism. At the beginning at the stage of Level 0, wireless node is it count to zero to go bankrupt, succeed in when conveying, the contention window maintains the minimum. But it does not need to stay while collide, increase the size of the window with the exponential directly, enter the stage of the next Level. At the stage of Level 1, must is it succeed in to transmit the number of times and is greater than transmitting failing the number of times once, can just shorten the competition window, and one Level before carriage return. On the contrary, the number of times is greater than transmitting the successful number of times once as transmitting failing, can just increase the contention window, enter the next Level, So we can express Level SCC stage:

$$\textit{Level SCC} = |\,\text{success\_counter} - \text{collision\_counter}\,| \leq SCC$$

Accordingly, in the OAB algorithm the reducing of the number of times must be within the range in this Level value. Regard as work number of times is it fail number of times greater than SCC of Level at the value, carriage return one Level to subtract. On the contrary, as fail number of times subtract successful number of times greater than SCC of Level at the value, will enter the next Level. The way to let contention window size, can is it accord with the flow of load instantly most to stay mainly, can succeed by time of collisions, change most proper contention window size. So the Oneself Adjusts transfers by exponential type mechanism of algorithm in any network load, can is it than EIED algorithm and LILD algorithm kind network transmit efficiency to offer.

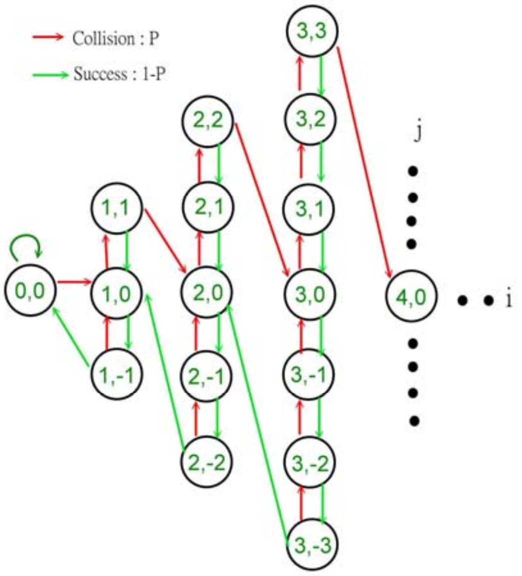

Figure 4. OAB algorithms of Markov Chain Model.

D. Calculating

Suppose the probability of colliding is P, it is 1-P to transport the probability succeeding . There are 4 kinds of situations while transition in a states of Markov. Probability that these 4 kinds of Oneself Adjusts is $P\{[s(t+1),b(t+1)]|[s(t),b(t)]\}$. State $[s(t),b(t)]$ reaches the probability of state $[s(t+1),b(t+1)]$, can show with the following 4 pieces of posture respectively：

$$P\{(i,k)\,|\,(i,k+1)\}=1-P \tag{1}$$
$$P\{(i,0)\,|\,(i,k)\}=1-P \tag{2}$$
$$P\{(i,k+1)\,|\,(i,k)\}=P \tag{3}$$
$$P\{(i+1,k)\,|\,(i,k)\}=P \tag{4}$$

We put the posture of equations (1), (2), (3), (4) in order into Matrix of One-step transition probility. Make matrix P transition probability matrix for this step. $P[s(t+1),b(t+1)]$ shows time t is in state $[s(t),b(t)]$ but transfers to the probability of $[s(t+1),b(t+1)]$ when time t+1. P^n represents probability matrix that n step transition, P^2=P • P，P^3= P^2 • P and so on and so forth. According to the theory of Markov limiting probability, when n is reached infinitely greatly, $P^n_{[s(t),b(t)][s(t+1),b(t+1)]}$ will disappear into a certain value.

$$b_{i,k}=\lim_{t\to\infty} P\{s(t)=i,b(t)=k\} \tag{5}$$

Let equations (5) express stationary distribution of this Markov Chain. $b_{i,k}$ express it under the stable state, stay in the state for a long time <i, k > probability. So the one that can be tried to get $b_{i,k}$ by the cubic procedure of the following two antithetical couplets is solved.

$$b_{j,k}=\sum_{x=0}^{i}\sum_{y=0}^{k} b_{x,y}P_{(x,y)(i,k)} \tag{6}$$

$$\sum_{i=0}^{i}\sum_{k=0}^{k} b_{i,k}=1 \tag{7}$$

The meaning of equations (6) is to multiply by and enter the probability of state (i,k) from (x,y) all probability with state (x,y). And the meaning of equations (7) is to add and always stand up all probability with state (i,k), this adds total value and equals 1.

And then calculate the work station transmit probability τ of a news frame in the any time slot. The work station will not transmit the frame of the data until getting the value of the state change counter of counting backoff for -1 slot time, so τ can be regarded as each probability total of $b_{(i,j-1)(i,j)}$ state.

$$\tau=\sum_{i=0}^{m} b_{(i,j-1)(i,j)} \qquad 0\le i\le m \tag{8}$$

In the steady state, work station transport probability, news of frame τ all, this make we may inference produce the formula of P. Can be used for calculating the transmission amount of the data frame after deriving out the formula of τ . In order to calculate the transmission amount of the data frame, we must analyse the incident that will happen at any time slot first. Define P_{tr} in order to there is probability that a news frame transport at least in the wanton for the moment slot work station. If there is competition channel of a work station n, the probability that each work station transport is τ , the formule is as follows：

$$P_{tr}=1-(1-\tau)^n \tag{9}$$

Equations (9) is the probability not transport the frame of the data with all probability 1 minus work station of n, get and amount to the transition probability with a work station at least.

And then calculate it is P that the frame of transport the probability succeeding. It is that can't be collided that the frame of the data can transport the most important condition succeeding. That is to say that in case of once transport at least, there can only be a work station to transport. Above-mentioned situations can be regarded as condition probability, will calculate formulae as follows:

$$P_s=\frac{n\tau(1-\tau)^{n-1}}{1-(1-\tau)^n} \tag{10}$$

Equations (10) express it in a situation that a data frame is transported at least, In the n work station, only one is being transporting, one other n-1 are not being transporting, would not collide in this way.

Then should derive out throughput of the formula which measure S. Define S in order that the proportion is using and succeeding in transport the datas location how much time this channel has. So datas transmitting S when being for being wanton for datas where slot transport and when ratio, slot time of length. Can express with the following formulae S it:

$$S = \frac{E(\text{In one slot time of data transmitting})}{E(\text{lengh of slot time})} \quad (11)$$

$E[P] =$ The average datas frame loads of the length

$P_{tr} P_s =$ Probability that the data frame succeeds transmitted at any time slot

$P_{tr} = (1 - P_s) =$ probability that the data frame collide transmited at any time slot

$(1 - P_{tr}) =$ probability that the channel idle for any time slot

Our goal is to require the biggest saturation throughput amount S. When the number n of work station of the network is regula, Value of τ is only to have something to do with minimumly contention window for value W and the value m. That is to say adjust i and W, let value of τ try one's best convergence $\frac{1}{n\sqrt{T_c/2}}$ can receive most heavy saturating throughput S.

IV. Simulation Results

In this section, we study the performance improvement of the proposed OAB as compared to the related backoff schemes, including DCF, EIED and LILD. The simulation results presented in this section were obtained using a simulator NS-2. In the **s**imulation, we consider the network and transmit the materials under the saturated condition. The number of wireless node is set as 10 to 100. We assume that there is no hidden terminal in the network. The parameter values of IEEE 802.11 wireless network (PHY: DSSS) are shown in Table III.

Fig. 5 shows all backoff throughput curve of the algorithm. Can find out to pursue, while the wireless node becomes many, the throughput will be reduced. DCF rate of descent is the fastest. EIED and LILD algorithm good than DCF at efficiency of throughput, OAB algorithm is it stay concept solve EIED and LILD shortcoming. So OAB can all offer better throughput under different network load states. Fig. 6 describes all wireless nodes, transmit the probability of colliding. Such as expecting to expect, in case of different network load, OAB algorithm than others algorithm have lower collision probability. Fig. 7 is while describing the per unit to succeed transmit, the average quantity of channel free time. According to our observation, though OAB algorithm to slightly increase in channel free time on this efficiency, but can reduce and transmit the colliding rate effectively, raise the systematic throughput.

TABLE III. 802.11 The protocol contention window size parameter value.

Packet payload	8184 bits
MAC header	272 bit
PHY header	128 bit
ACK	112bit+PHY header
Channel bit rate	1 Mbit/s
Slot time	50μs
DIFS	128μs
SIFS	28μs
Propagation Delay	1μs
CWmin	32
CWmax	1024

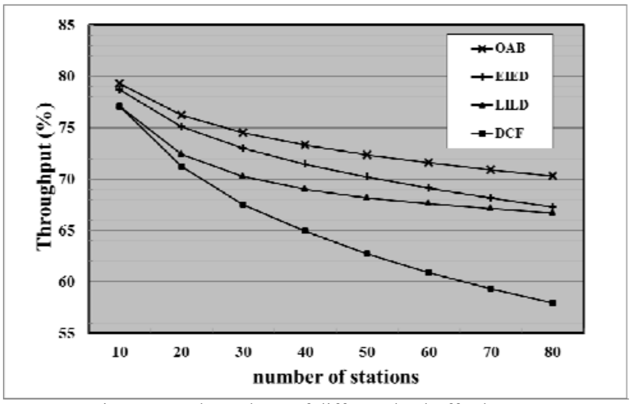

Figure 5. Throughput of different backoff schemes.

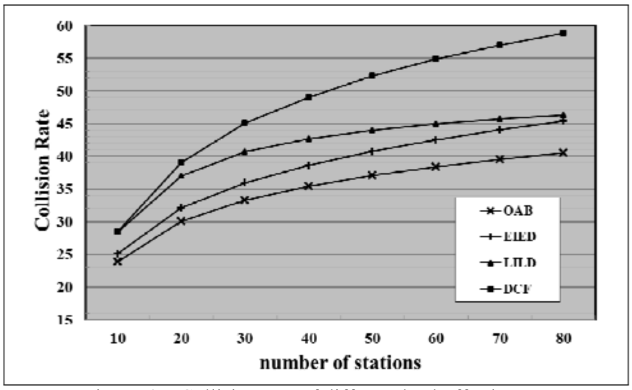

Figure 6. Collision rate of different backoff schemes.

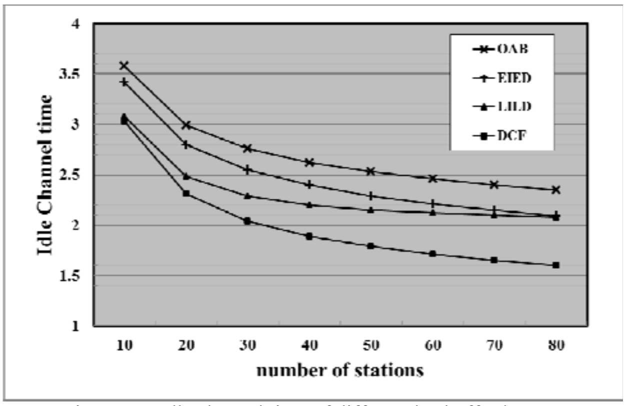

Figure 7. Idle channel time of different backoff schemes.

V. CONCLUSION

This paper proposes a Oneself Adjusts Backoff contention window control mechanism. The way to utilize OAB, revise the shortcomings of EIED and LILD. The difference which transmits success or failure happens in the node of the network, while reaching the critical value, the state change will just take place. So, the contention state of the channel will stay in the proper size of contention window and achieve the stable system and purpose of improving efficiency. According to experimental result analysis, under different network load, OAB perform algorithm can improve systematic throughput and person who collide by a large margin. In the future work, we will analyze OAB algorithm of the mathematics model, estimate the systematic efficiency of the whole.

VI. ACKNOWLEDGEMENT

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