A Deterministic Back-off Algorithm for Wireless Networks

Jung-woo Jin*, Kyung-Jun Kim*, Dong-hwan Kim*, Ho-seung Lee*, Ki-jun Han**
Department of Computer Engineering, Kyungpook National University, Korea
Tel : +81-053-950-5557 Fax : +81-053-957-4846
E-mail: *{deux8, kjkim, iondh, leho678}@netopia.knu.ac.kr, **kjhan@bh,knu.ac.kr

Abstract:

Binary Exponential Back-off (BEB) scheme is widely adopted in both wire and wireless networks for collision resolution. The BEB suffers from several performance drawbacks including long packet delay and low utilization since it doubles the back-off size after each collision. In addition, operation of the BEB algorithm may lead to the last-come-first-serve result among competing users and the BEB is further unstable for every arrival rate greater than 0 due to its random access property[1,2]. In this paper, we propose a deterministic back-off algorithm to reduce contention interval as much as possible for accessing the channel without collision in the back-off process. Simulation results show that our scheme offers a higher throughput as well as a lower packet transfer delay than the BEB by taking advantage of its lower collision ratio in saturation state.

Binary Exponential Back-off(BEB), Back-off, collision

1. INTRODUCTION

In recent years, the proliferation of portable and laptop computers has led to wireless technology being required to support wireless connectivity. Since a wireless device relies on a common transmission medium, the transmissions of the network stations must be coordinated by the medium access control (MAC) protocol.

A major technical challenge in wireless communication is the selection of suitable multiple access control scheme to efficiently arbitrate wireless devices on a common air interface. a variety of MAC schemes have been proposed, e.g. the multiple access schemes such as Slotted ALOHA and CSMA/CA, and the demand-assignment schemes such as Packet Reserve Multiple Access (PRMA), Distributed Queuing Request Update Multiple Access (DQRUMA), and Random Addressed Polling (RAP)[2].

One of the most important components in MAC design is back-off algorithm which is needed when collision occurs either in data transmission or in bandwidth reservation. The Binary Exponential Back-off (BEB) algorithm is the most widely used in wireless networks such as cellular systems and wireless LANs.

However, the BEB suffers from several performance drawbacks due to its randomness inherited in its operation. First, the BEB algorithm may lead to last-come-first-serve among competing stations, which produces the "capture effect" that allows a single or a few "winning" users to dominate the available bandwidth. Second, the BEB is unstable for every arrival rate greater than 0. In this paper, we propose a deterministic back-off algorithm to reduce contention interval as much as possible for accessing the channel without collision in the back-off process. Simulation results show that our scheme offers a higher throughput as well as a lower packet transfer delay than the BEB by taking advantage of its lower collision ratio in saturation state[3,4].

The paper is organized as follows. The operation of BEB algorithm and its drawbacks will be described in Section II. Section III presents our deterministic back-off algorithm. Experimental results are presented in Section IV. Finally, we conclude the paper in Section V.

2. THE BINARY EXPONENTIAL BACK-OFF(BEB) ALGORITHM

The BEB algorithm used in wireless network operates in the following way. If a packet has been transmitted unsuccessfully i times, the packet will be retransmitted again k slots later, where k is a random number uniformly distributed over the interval of $[0, 2^{3+i} - 1]$. If a packet is transmitted successfully or is expired and dropped, i is reset to 0. The philosophy behind the BEB algorithm is that, for a given packet, a higher number of unsuccessful retransmissions imply that more stations are competing for the available bandwidth, and, as a result, a larger back-off window should be adopted to reduce the probability of collision[3,4,5,6].

Under high loads, there are always stations challenging another competition which has lost in the previous competition as well as stations newly joining the competition. At this time, the new joiners are given shorter CW's while the backlogged stations are assigned longer CW's. So, the slots positioned earlier in CW have a much higher probability to be chosen under high loads in the BEB algorithm. This is undesirable because the slots that have been chosen are more likely to be chosen again. Further, the BEB may generate a number of collisions at high traffic intensities, as a result, a long contention interval is required to determine the winner. This results in decrease of performance such as throughput and the packet delay[3,4,5,6].

In this paper, we propose a deterministic back-off algorithm to reduce contention interval as much as possible for accessing the channel without collision in the back-off process..

3. PROPOSED SCHEME

In our algorithm, each station is initially given back-off time based on its ID during the registration or authentication procedure by the Base Station (BS) in the cellular network or the Access Point (AP) in the wireless LAN. In other words, the back-off time is not randomly chosen as in the BEB, but is given a fixed value by BS or AP when each station enters the network. Once, a station is assigned the back-off time, it starts a counter called 'Countdown Counter (CC)'. The CC is decremented, beginning from the initial back-off time, by one every time an empty slot is sensed, and tries transmission when it reaches 0 as in the BEB. The station whose CC has reached 0 is given a new back-off time by BS or AP using a beacon messages over the downlink. In our scheme, the station which is given the smallest back-off time has the highest priority to access channel. To guarantee fairness for accessing the channel among stations in the network, each station decrements its back-off time by one for every frame. In this way, all stations share the channel by handing over the prior right among each other.

For example, in Fig. 1(a), N2 can access the second slot of the current frame since its back-off time is '1'. Similarly, N4 can access the fourth slot, and so on. So, N2 can has priority to transmit its data since it has the smallest back-off time. After the current frame has passed, each station decrements its back-off time by one. Assuming that N1 and N3 join to contend with the backlogged N4 as illustrated in Fig. 1(b). If N3 is given 3 as its back-off time, then there will be a collision when its CC becomes zero. However, the collision can be resolved if the competing station are informed of collisions by BS or AP since they again contend with others using new back-off times.

Station id	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8
Back-off Time	-	2	-	4	-	-	-	-
Countdown counter	-	2	-	4	-	-	-	-

(a) Initial back-off times and CC

Station id	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8
Back-off Time	4	1	2	3	-	-	-	-
Countdown counter	4	-	2	2	-	-	-	-

(b) Back-off times after a frame has passed

Station id	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8
Back-off Time	3	4	1	2	-	-	-	-
Countdown counter	2	-	1	2	-	-	-	-

(c) Back-off times after two frames have passed

Station id	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8
Back-off Time	2	3	4	1	-	-	-	-
Countdown counter	1	-	-	1	-	-	-	-

(d) Back-off times after three frames have passed

Fig. 1. Back-off times and CC for slot access

4. SIMULATION

In this section, we evaluate performance of our deterministic back-off algorithm. The system model for analysis is a Basic Service Set of wireless LAN which consists of an Access Point (AP) and stations. It is assumed that all stations only transmit their packets to AP and AP does not generate its own packets except ACK packets. As shown in Fig. 2, each station transmits its packet to the AP and the AP replies ACK packet to the corresponding station.

Several assumptions have been made to reduce the complexity of the simulation model :

- The effects of propagation delay are neglected.
- The channel is error-free that means that each transmitted packet was successfully and correctly received at its destination.
- Stations in BSS have the ability to detect collision.
- Channel is in the saturation state.

In addition, each station is assumed to be a Poisson traffic source and the packet size is fixed as 45us including overhead. The parameters used for performance evaluation are listed in Table 1.

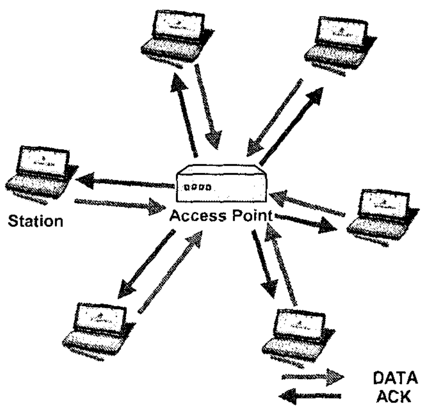

Fig. 2. System Model

Table 1 System parameter

Symbol	Meaning	Value
N	Number of stations	Variable
T_{slot}	aSlot_time	9us
T_D	DIFS	34us
T_{ACK}	ACK transmission time	5us
T_p	Packet transmission time	45us

The gathered simulation results allow us to determine the realized throughput and the mean packet delay versus number of stations for back-off time parameters determined by BS or AP

Figure 3 shows throughput in the saturation state. As observed in this graph, our mechanism offers a higher throughput than the BEB algorithm in the saturation status.

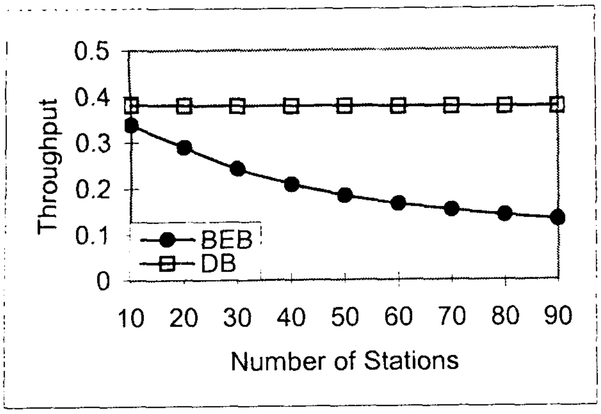

Fig. 3 Throughput versus number of stations

Figure 5 shows the mean packet delay measured from the start of packet generation to the acknowledgement of its proper reception. Since the BEB algorithm doubles back-off window size for every collision without considering anything, the station may sometimes experience a long delay before accessing the channel to transmit its packets. However, our algorithm can reduce the delay by using a deterministic back-off times in the saturation state.

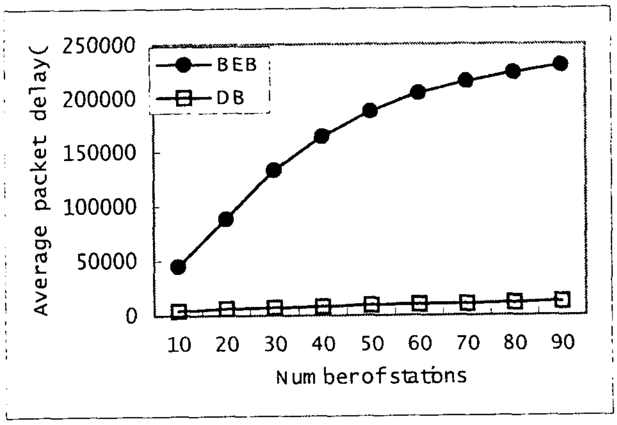

Fig 4. Average packet delay versus number of stations

As shown in Fig. 6, the our algorithm generates a fewer collisions than the BEB algorithm at high traffic intensities.

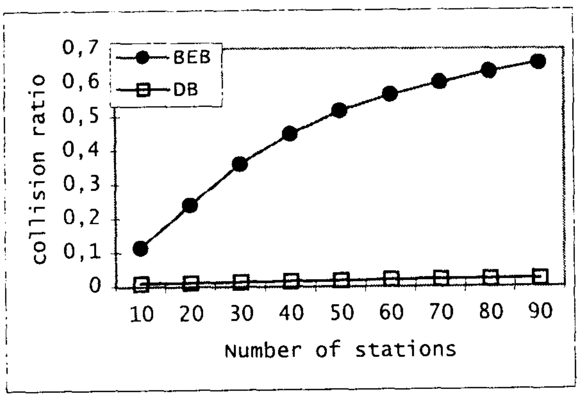

Fig 5. Collision ratio versus number of stations

5. CONCLUSION

In this paper, we presented an analytical model of the throughput for IEEE 802.11e EDCA protocol. In our analytical model, we assumed that each priority class used non-overlapped contention period. We have shown that the EDCF priority scheme is quite effective to support controlled QoS. Our model was validated via computer simulations and a sound agreement between the numerical results by both was observed.

References

[1] F. Cali, M. Conti, and E. Gregori, "IEEE 802.11 Protocol: Design and Performance Evaluation of an Adaptive Backoff Mechanism," IEEE JSAC, Vol. 18, No. 19, Sep. 2000, pp. 1774-1786, 2000..

[2] G. Bianchi, L. Fratta, and M. Oliveri, "Performance evaluation and enhancement of the CSMA/CA MAC protocol for 802.11 wireless LANs," in Proc. PIMRC 1996, Taipei, Taiwan, Oct. 1996, pp. 392-396.

[3] M. Natkaniec and A. R. Pach, "An Analysis of the Backoff Mechanism used in IEEE 802.11 Networks," Computers and Communication, 2000, Fifth IEEE Symposium on, 3-6 July 2000.

[4] G. Bianchi, "Performance analysis of the IEEE 802.11 distributed coordination function," IEEE JSAC, Vol. 18, No. 3, Mar. 2000, pp. 535-547, 2000.

[5] M. Natkaniec and A. R. Pach, "PUMA - a new channel access protocol for wireless LANs," Wireless Personal Multimedia Communications, 2002 The 5th International Symposium on , Volume: 3, 27-30 Oct. 2002

[6] C. Li and Y Chen, "Collision Based Multiple Access Scheme for Wireless Networks", in Proceedings of IEEE PIMRC2002, Lisbon, Portugal, September 15-18, 2002.