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Considering Backoff Algorithms Efficiency Focused on the Effect of Wall and Floor Materials for Indoor Radio Network

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Abstract. In this paper, we introduce a new theoretical scheme for evaluating the performance of backoff algorithms focusing on multiple types of wall and floor material such as: concrete, wood, glass and brick. The proposed scheme is an extension and combination between Bianchi and Multi-wall-floor model, by applying discrete Markov chain theorem. In addition, we also propose two backoff algorithms which can improve the saturated throughput efficiency of IEEE802.11 wireless local area network (WLAN). The proposed backoff algorithms are called Binary Exponential Increment Half Decrement backoff algorithm (BEIHD), and Half Binary Exponential Increment Double Decrement backoff algorithm (HBEIDD). The numerical results show that significant improvement saturated throughput of HBEIDD backoff algorithm operates well for plywood wall and wood floor materials in indoor environment.

Introduction

In a realistic indoor wireless radio network modeling, a popular model is used for analyzing the performance of binary exponential backoff algorithm (BEB) for IEEE802.11 WLAN [1] as well-known Bianchi's model [2]. However, this model does not considering the effect of wall and floor materials in indoor envelopments. Therefore, the main idea in this paper proposes a new theoretical model by combining Bianchi model and multi-walls-floors model [4][5] under discrete Markov chain theorem. Moreover, we also propose the BEIHD and HBEIDD backoff algorithms, and the performances of both algorithms are compared with a legacy BEB backoff algorithm in term of saturated throughput efficiency under different path loss coefficients of wall and floor materials. The accuracies of numerical results use real values of attenuation in research [3] and [4]; furthermore, the physical layer and channel access parameters in this research use Carrier Sense Multiple Access with Collision Avoidance and Request-to-Send Clear-to-Send (CSMA/CA RTS CTS) protocol. This paper is organized as follows. Saturation throughput of all backoff algorithms are calculated in Section 2. The numerical results are then presented and discussed in Section 3. Finally, the summary is given in section 4.

Saturated Throughput Calculation

Basically, there are two types of radio wave propagation in building environment: (1) line of sight (LOS) and (2) none line of sight (NLOS) as shown in Fig. 1.

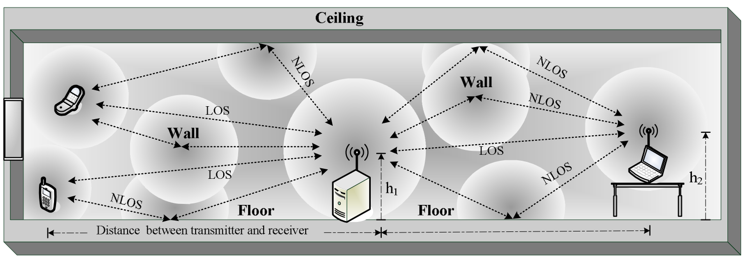


Fig. 1. Single reflection model for indoor radio network.

From Fig.1, we use the similar concept as appeared in [3-6] to calculate the received power, and which is given by

$$P_{\text{receiver}} = P_{\text{transmitter}} + G_{\text{T}} + G_{\text{R}} - \text{Path loss} - \text{Reflection loss}, \tag{1}$$

where by

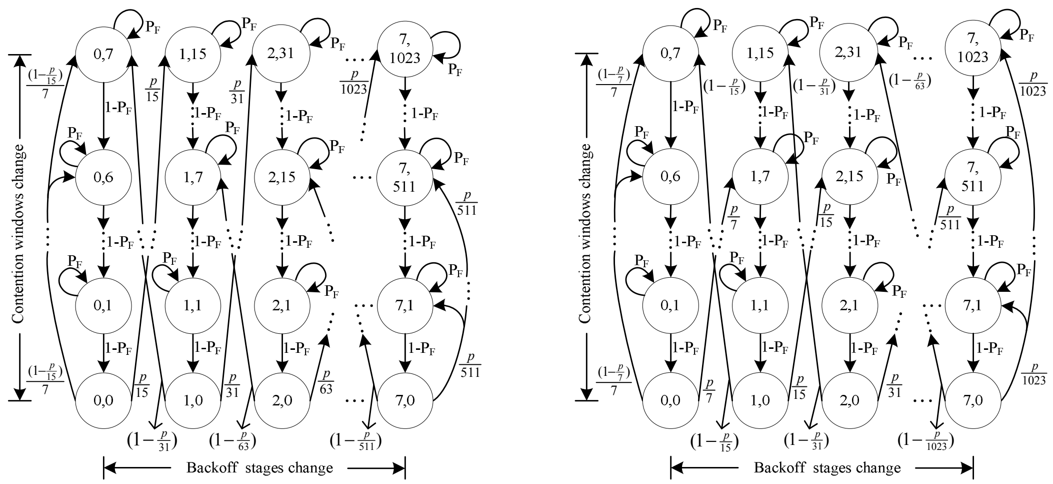
$$\text{Path loss LOS: 2.4 GHz} = 37.82 + 14\log(d), \text{ and NLOS: 2.4 GHz} = 40.79 + 37.5\log(d), \tag{2}$$

$$\text{Path loss (LOS: 5 GHz)} = 45.74 + 17\log(d), \text{ and NLOS: 5 GHz} = 53.68 + 14\log(d), \tag{3}$$

$$\text{Reflection loss} = n_{\text{f}} f + n_{\text{w}} w, \text{ and } d = \text{distance between transmitter and receiver (m)} \tag{4}$$

In this research, parameter $P_{\text{transmitter}}$ is the transmitted power in watt (the legal limit for radiated power of indoor wireless LAN adapter is generally set to 100 mW or 20 dBm). G_{T} is the antenna gain of transmitter (assigned G_{T} = 1 or 0 dB), G_{R} is the antenna gain of receiver (assigned G_{R} = 1 or 0 dB). The height of transceiver h_1 and h_2 both are fixed at 1.2 meters, n_{f} is the number of floors (assigned n_{f} = 1), n_{w} is the number of walls (assigned n_{w} = 1). Parameter f is the floor attenuation factor and w is the wall attenuation factor. In a realistic indoor radio network, a packet loss occurs from transmission loss due to noises, path loss, reflection loss, and collision phenomenon.

Backoff algorithm is a technique to reduce the collision problem of the transmitted data packet in wireless radio network. In IEEE802.11 WLAN standards [1], the BEB algorithm is a legacy backoff algorithm that it is widely analyzed in [2] as well. The new models of proposed BEIHD and HBEIDD backoff algorithms are modeled in fixed backoff stage and fixed contention window sizes technique (FBFC) as shown in Fig.2 (a) and (b).



(a) (b)

Fig. 2. (a) BEIHD backoff algorithm and (b) HBEIDD backoff algorithm in FBFC model.

From Fig.2, the minimum and maximum of contention window sizes ($CW_{\min}$,$CW_{\max}$) are fixed at 8 and 1024 timeslots, respectively. Also, the maximum of backoff stage is varied from 0 to 7 stages. We use the global balance equation concept in queuing theorem to derive the transmission probability (τ) for calculating the saturated throughput of BEB, BEIHD and HBEIDD backoff algorithms, and which are given by

$$\tau_{\text{BEB}} = 1/[1 + B_1 + B_1B_2 + B_1B_2B_3 + B_1B_2B_3B_4 + B_1B_2B_3B_4B_5 + B_1B_2B_3B_4B_5B_6 + [(B_7/(1-B_7))B_1B_2B_3B_4B_5B_6]], \tag{5}$$

$$\tau_{\text{BEIHD}} = 1/\left(1 + B_1 + B_2 + B_3 + B_4 + B_5 + B_6 + B_7\right), \text{ and } \tau_{\text{HBEIDD}} = 1/\left(1 + \left(1/B_7\right) + B_1 + B_2 + B_3 + B_4 + B_5 + B_6\right), \tag{6}$$

where by $B = (1-P_F)/(1-2P_F)$, $B_1 = (p/15)\sum_{L=1}^{15} B^L$, $B_2 = (p/31)\sum_{L=1}^{31} B^L$, $B_3 = (p/63)\sum_{L=1}^{63} B^L$, $B_4 = (p/127)\sum_{L=1}^{127} B^L$

$B_5 = (p/255)\sum_{L=1}^{255} B^L$, $B_6 = (p/511)\sum_{L=1}^{511} B^L$, $B_7 = (p/1023)\sum_{L=1}^{1023} B^L$

Parameter p is a collision probability, and P_F is a suspended backoff countdown mode probability (assigned: $P_F = 0.05$). Channel access scheme in this paper uses the CSMA/CA RTS CTS protocol. The transmission probability (τ) of CSMA/CA RTS CTS protocol will use to calculate the saturated throughput performance of all backoff algorithms by applying equations (1) to (7). The saturated throughputs can be calculated from

$$\text{Saturated throughput} = \frac{P_S P_{tr}(MSDU \times 8)P_{\text{ERROR}}}{(1-P_{\text{tr}})T_{\text{aTimeSlot}} + P_{\text{tr}}P_S T_S + P_{\text{tr}}(1-P_S)T_C} \quad , \qquad (7)$$

where by $p = 1-(1-\tau)^{n-1}$, $P_{\text{tr}} = 1-(1-\tau)^n$, $P_S = n\tau(1-\tau)^{n-1}/[1-(1-\tau)^n]$, and $P_C = 1-P_S$,

$T_S = T_{\text{DIFS}} + T_{\text{RTS}} + T_{\text{CTS}} + 3T_{\text{SIFS}} + 4T_{\text{delay}} + T_{\text{Data}} + T_{\text{ACK}}$, and $T_C = T_{\text{RTS}} + T_{\text{DIFS}} + T_{\text{delay}}$,

$P_{\text{ERROR}} = 1-(1-BER)^{MSDU\times 8}$, $E_b/N_o = P_{\text{receiver}}/(KT_{\text{SYS}}BW)$,

$BER_{\text{BPSK}} = (1/2)/[1-(1/\sqrt{1+(1/(E_b/N_o)})]$

Parameter P_S is successful transmission probability, P_{tr} is transmission probability, P_C is unsuccessful transmission probability, n is number of contending stations, T_S is successful transmission period, and T_C is collision transmission period. Besides, this paper assigns: bit error rate (BER) = 10^{-5} , Boltzman's constant = 1.38×10^{-23} J/k, signal bandwidth (BW) = 20 MHz, and system noise temperature (T_{sys}) = 30°+273 k. The time periods of IEEE802.11b standard at data rate 11-Mbps is assigned: T_{SIFS} = 10 μs, T_{DIFS} = 50 μs, $T_{aTimeSlot}$ = 20 μs, T_{delay} = 1 μs, T_{RTS} = 352 μs, T_{CTS} = T_{ACK} = 304 μs, and T_{Data} = 2311.45 μs. Additionally, the time periods of IEEE802.11a standard at data rate 54-Mbps is assigned: T_{SIFS} = 16 μs, T_{DIFS} = 34 μs, $T_{aTimeSlot}$ = 9 μs, T_{RTS} = T_{CTS} = T_{ACK} = 24 μs, and T_{Data} = 398.7 μs. Digital modulation scheme in this research uses binary phase shift keying (BPSK).

Numerical Results

Similarly to the work in [3], the attenuation factors are assigned: Concrete wall = 16 dB, Plywood wall = 0.9 dB, Gypsum wall = 1 dB, Rough chipboard wall = 0.9 dB, Glass plate wall = 2.5 dB, Concrete block = 10 dB, Brick floor = 3.66 dB, Concrete floor = 19 dB and Wood floor = 0.9 dB. Open source SCILAB simulation tool is used for calculating the saturated throughputs. Fig. 3 compare the saturation throughput of BEB backoff algorithm in NLOS wireless channel by changing the types of wall materials, but the type of floor is concrete material.

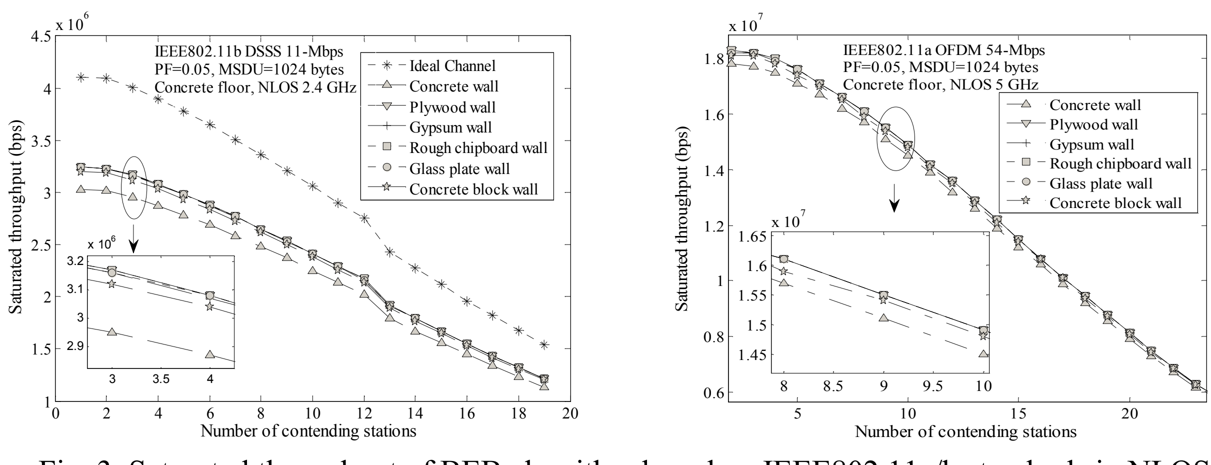
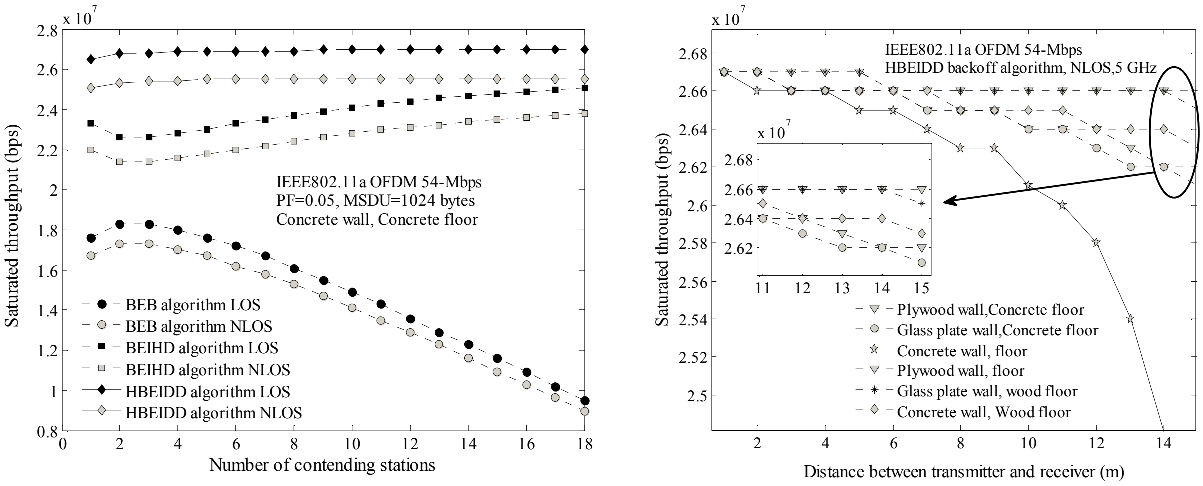


Fig. 3. Saturated throughput of BEB algorithm based on IEEE802.11a/b standards in NLOS.

In Fig.3, the results represent that the saturation throughput of the plywood, gypsum, rough chipboard, and glass plate walls are higher than the smooth concrete wall. In addition, the results show that the saturated throughput is reduced when the number of contending station is increased. Fig. 4 (a) compares the saturated throughput efficiencies of all backoff algorithms in LOS and

NLOS channels. The results guarantee that the proposed HBEIDD backoff algorithm technique is better than the BEB and BEIHD backoff algorithms in concrete wall and floor material. The relation between saturated throughput performance and distance of transceiver of HBEIDD backoff algorithm is shown in Fig.4 (b). The result significantly highlights that the saturated throughput of glass plate and plywood walls are better than the concrete wall and floor materials.



(a) (b)

Fig. 4. (a) Saturated throughput comparison of all backoff algorithms in LOS and NLOS channel. (b) Performance of HBEIDD backoff algorithm in different types of wall and floor.

Summary

Our research underlines the importance of wall and floor materials based on the saturation throughput performance of proposed BEIHD and HBEIDD backoff algorithms. The importances of our work confirm that the proposed backoff algorithms can improve saturated throughput performance for wireless radio network in wood wall and floor room. In addition, we believe that our research can help the building contractor to select the suitable types of wall and floor material.

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