AN ANALYSIS OF THE MODIFIED BACKOFF MECHANISM FOR IEEE 802.11 NETWORKS

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Abstract
This paper describes a modification of the backoff mechanism for IEEE 802.11 networks. The efficiency of the modified backoff mechanism compared to that is currently used in the standard was analyzed. The realized throughput and the mean packet delay for DSSS and FHSS physical layers for different number of stations were determined. The overall rate of collisions that occurred during transmission was compared for both backoff mechanisms.

Keywords
Wireless LANs, IEEE 802.11, backoff mechanism, performance analysis.

1. INTRODUCTION

We can observe the rapid growth of interest in wireless networking. The recent advances in the chip technology bring an evolution of portable devices like laptops, palmtops and PDAs (*Personal Digital Assistants*). Mobile data networks and wireless LANs WLANs empower these devices by connecting them to each other and to information we need wirelessly. The most well known standard that describes WLANs is IEEE 802.11 [3].

The most often medium access algorithm used is CSMA (Carrier Sense Multiple Access). In CSMA every contending station senses the carrier before the transmission. The WLANs use a mutation of that algorithm called CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance). This algorithm has been employed by the DCF (Distributed Coordination Function) function of IEEE 802.11. In order to avoid collisions a random backoff mechanism has been used. It is based on a random slot selection from the Contention Window (CW). The stations start to transmit their frames in random moments to decrease the probability of collision.

The backoff mechanism has intensively been studied in the literature since the beginning of 70's. The idea of using the backoff mechanism in the MAC layer of the IEEE 802.11 standard has brought a new interest in such a mechanism. The proper selection of the backoff parameters is an essential issue for the network performance. For example, the problem of unequal slot selection was considered in [8]. Two modified backoff schemes, namely the weighted selection probabilities and the load adaptive selection were proposed. A simulation analysis of the CW parameter for the Direct Sequence Spread Spectrum (DSSS) physical layer was presented in [2]. The work [4] describes a simulation analysis of the backoff mechanism presented in the last version of IEEE 802.11. The realized throughput and the mean packet delay versus offered load for different CW parameters (CWmin and CWmax) and number of contending stations were presented. The optimal value of CWmin in dependence on the number of transmitting stations was determined.

This paper describes a modification of the backoff mechanism, which is called DIDD (Double Increment Double Decrement) and can be used in IEEE 802.11 networks. The main intention of the proposed scheme is to increase the overall efficiency (i.e. increase the throughput and decrease the mean packet delay) of the network consisting of a large number of stations under high load conditions. The work presents a simulation analysis of the DIDD backoff mechanism compared to the backoff that is currently used in the standard. It allows us to determine the realized throughput and the mean packet delay for the DSSS and FHSS physical layers for different number of transmitting stations. The overall number of collisions occurring during the transmission is compared for both backoff mechanisms.

2. DIDD Backoff Mechanism

The idea of modification of the backoff mechanism that is currently presented in the IEEE 802.11 standard was born during analyzing the slot selection from CW by active stations. One can notice a very unprofitable effect, which steps out in a network consisted of a large number of stations and working under heavy load. Because of the large number of stations the initial CW size is too small, independently of the physical layer type. At large values of offered load the large number of collisions is observed (the problem of the suitable selection of CW parameters in dependence on the number of contending stations was considered in [4]). This brings a high degradation of the network performance.

A station, which sent correctly its data frame, always reduces CW to the minimum value (CWmin). Let us consider the case, when a network operates under heavy load and each station has already prepared the next frame for transmission. The station starts the consecutive attempts of transmission, ending usually by the conflict. In order to avoid such a situation CW should be considerably large. After elapsing some time the station selects the slot from CW of a greater size and sends the frame with greater chances for the success.

The modification of the backoff mechanism relies on division of CW by half after every successful transmission of a data frame (see Fig. 1). This mechanism is called DIDD (Double Increment Double Decrement) backoff. When a network operates under heavy load, then this backoff scheme brings a significant reduction of collisions, so it should increase the network performance. Because the CWmin size is, as specified in the standard, different for DSSS, FHSS and IR, so the greater profit should be observed for a layer, where the CWmin size is smaller. Therefore, this is the case of FHSS.

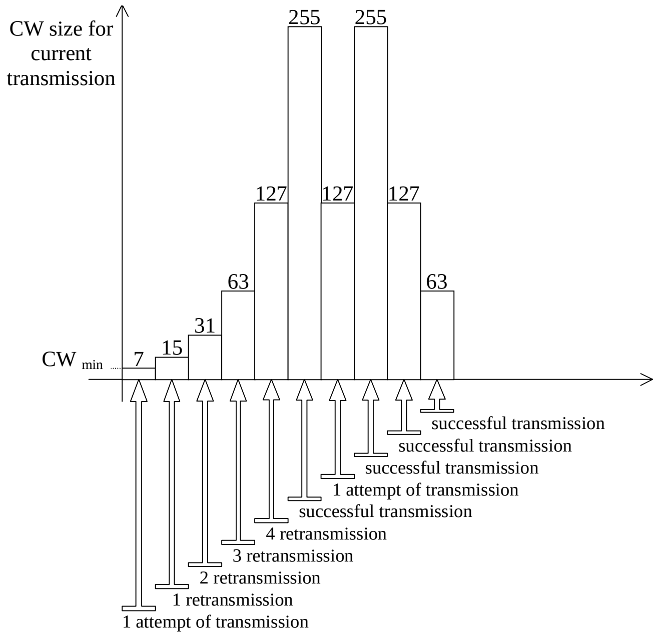

Fig. 1. Example of increase and decrease of Contention Window in the DIDD backoff scheme.

It should be interesting to find out, whether there is a situation in which the DIDD backoff mechanism would bring the degradation of the network performance. Such a situation could appears if most of stations in the same moment stop their transmissions (there are no packets in station buffers). In such a case, CW will be too wide and a lot of time will be wasted for counting down of too large backoff times. However, the DIDD backoff is able to adapt to the network conditions: after a number of transmissions the network exhibits the proper work. In practice, such a situation should not appear due to the fact of traffic averaging for a large number of stations.

3. SIMULATION RESULTS

The obtained simulations allow us to determine the realized throughput, the mean packet delay and the overall number of collisions versus offered load for both backoff mechanisms. The mechanisms were tested for 5, 25 and 100 stations transmitting frames of 1000 bytes. The study has been done for two different physical layers. The packet arrival process was Poisson. Several assumptions were made to reduce the complexity of the simulation models:

- The effects of propagation delay were neglected. This is a very realistic assumption if the transmission distances are of tens meters between stations.
- The channel was error free that means that each packet that was transmitted by the sender was successfully and correctly received by the receiver.
- There were no stations operating in the “power-saving” mode. All stations were “awake” all the time, so transmitted frames could immediately be received by the destination stations.
- The stations heard each other, that is the hidden station scenario was not considered.
- There was no interference from nearby BSSs.

The DATA + ACK mode of transmission was used. The network was configured to 2 Mbps medium capacity. Almost all parameters were taken from the IEEE 802.11 specification and adequate to DSSS and FHSS. The typical parameters for DSSS and FHSS are presented in Table 1. All other parameters used throughout all simulations are displayed in Table 2.

Table 1: The network parameters typical for the DSSS and FHSS layers.

Parameter	**Value for DSSS layer**	**Value for FHSS layer**
SIFS	10 µs	28 µs
DIFS	50 µs	130 µs
Length of slot	20 µs	50 µs
Initial size of CW (CWmin)	31 slots	15 slots
Maximum number of slots	1023 slots	1023 slots
Physical layer preamble	18 octets	96 µs

Table 2: The other network parameters used through all simulations.

Parameter	**Value**	**Parameter**	**Value**
Length of RTS	20 octets	Size of buffer for frames	10 frames
Length of CTS	14 octets	Timer T1	300 µs
Length of ACK	14 octets	Timer T3	300 µs
DATA header	32 octets	Number of retransmission of RTS frames	4
Length of asynchronous DATA frame	1000 octets	Number of retransmission of DATA frames	4
Number of stations	5, 25, 100	Capacity of medium	2 Mbps

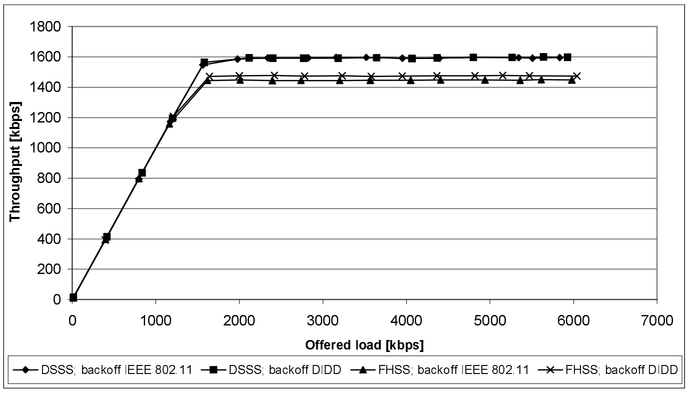

Fig. 2 The realized throughput versus offered load for both backoff mechanisms, DSSS and FHSS physical layers (5 stations).

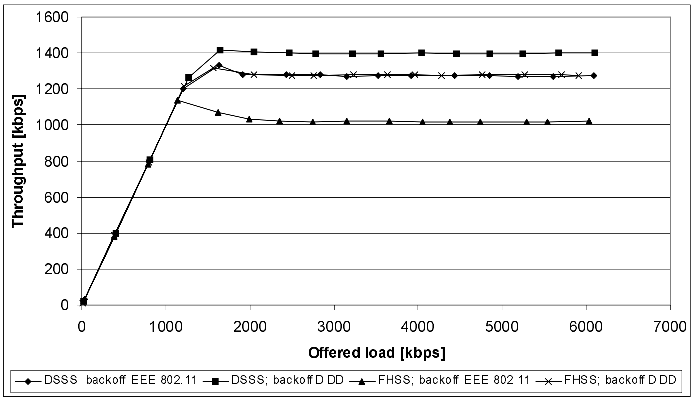

Fig. 3 The realized throughput versus offered load for both backoff mechanisms, DSSS and FHSS physical layers (25 stations).

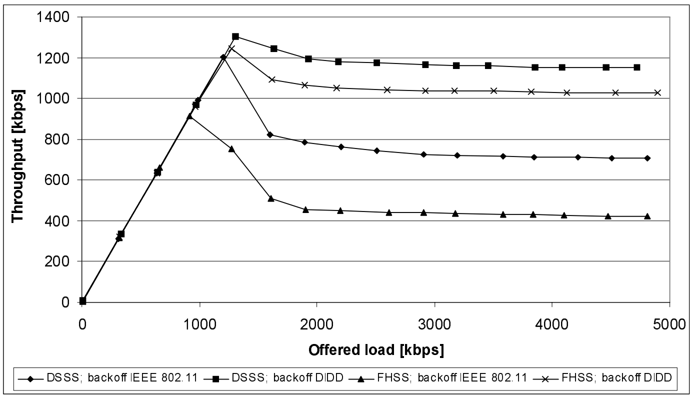

Fig. 4 The realized throughput versus offered load for both backoff mechanisms, DSSS and FHSS physical layers (100 stations).

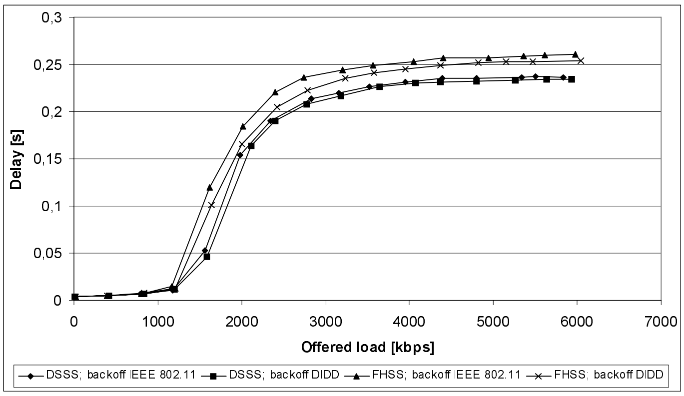

Fig. 5 The mean packet delay versus offered load for both backoff mechanisms, DSSS and FHSS physical layers (5 stations).

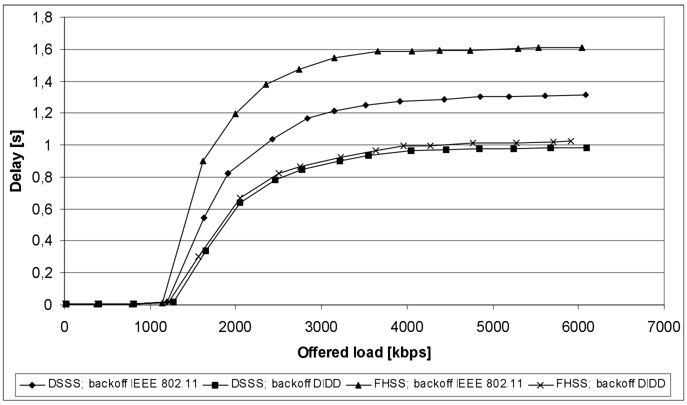

Fig. 6 The mean packet delay versus offered load for both backoff mechanisms, DSSS and FHSS physical layers (25 stations).

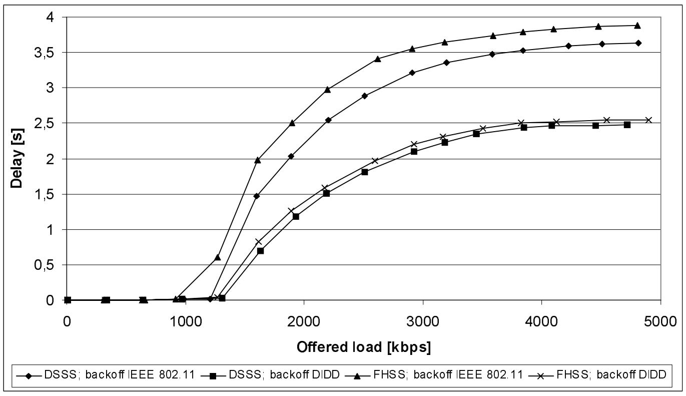

Fig. 7 The mean packet delay versus offered load for both backoff mechanisms, DSSS and FHSS physical layers (100 stations).

An analysis of the presented results allows us to draw several important conclusions. The tradeoffs between the realized throughput and offered load for both backoff mechanisms, FHSS or DSSS and for 5, 25 and 100 stations are presented in Figs. 2 - 4. The linear growth of the realized throughput for small values of the offered load is observed in all cases. The throughput achieves its saturation after exceeding a certain value of the offered load for a small number of stations. Independently of the type of the backoff mechanism the higher throughputs are observed for the network consisting of 5 stations, which utilizes DSSS. The differences are much higher for larger number of stations. Some maxima of throughputs are observed for 100 stations. The degradation of throughput can be observed for the IEEE 802.11 backoff. This degradation is much smaller for DIDD backoff.

The tradeoffs between the mean packet delay and offered load for both backoff mechanisms, both physical layers and 5, 25 and 100 stations are presented in Figs. 5 - 7. The low increase of the mean packet delay for low offered loads can be observed. It is of some milliseconds. The high growth of the mean packet delay after exceeding a certain value of offered load can be further noticed. It attains the constant level for heavy offered loads. The maximum values of the mean delay are very similar for both backoff types in the case of 5 stations. The number of stations has a little influence on the shape of the obtained characteristics, but large on the mean delay. For the DIDD backoff and 25 stations the mean packet delay attains the same value independently of the physical layer type. The largest values of the mean packet delay are attained for 100 stations, especially for the IEEE 802.11 backoff, similarly to the network consisting of 25 stations.

The overall number of collisions that occurred during simulation runs as a function of the offered load was analyzed. The shape of obtained plots is similar to that for the mean packet delay. The low number of collisions for low offered network load can be observed, then this number rapidly grows and saturates on the constant level. The overall number of collisions in each considered case is smaller when using the DIDD backoff. The decrease of the number of collisions brings the overall growth of the network performance.

4. CONCLUSIONS

The paper presents a new backoff mechanism for IEEE 802.11 WLANs called DIDD. It could be introduced with the aid of a little modification of the backoff that is currently proposed in the IEEE 802.11 standard. The DIDD backoff mechanism is especially designed for a network consisting of a large number of stations and working under heavy loads. It reduces the number of collisions, so brings the growth of the network efficiency. The paper presents the network efficiency for the DSSS and FHSS physical layers. The obtained results allows us to draw some general conclusions briefly presented below.

- The growth of the number of stations at large values of offered load causes the degradation of the network performance independently of the type of the physical layer.
- The usage of the DSSS physical layer increases the network performance, especially for a large number of stations (the growth of the network efficiency for the DSSS layer is caused by the larger CWmin size, Inter Frame Space and CW slot times compared to those defined for FHSS).
- The DIDD mechanism brings an improvement of the network efficiency, especially for large number of stations and values of offered load.
- The usage of the DIDD backoff mechanism causes the growth of throughput by more than 9% for DSSS and 25% for FHSS in the case of 25 stations. For 100 stations, this growth is of 65% for DSSS and 145% for FHSS.
- The usage of the DIDD backoff mechanism causes the decrease of the mean packet delay by more than 23% for DSSS and 37% for FHSS in the case of 25 stations. For 100 stations, this decrease is of 30% for DSSS and 35% for FHSS.
- The usage of the DIDD backoff mechanism brings a significant fall of the number of collisions for a large number of stations at large values of offered load (more than 2,5 times for FHSS and 100 stations).

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