Evaluating Wireless LAN Access Methods in Presence of Transmission Errors

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***Abstract*— Several modifications of the IEEE 802.11 DCF access method have been proposed recently to improve the performance of wireless LANs. Up to now, such proposals have only been compared under ideal channel conditions. In this paper, we evaluate the impact of transmission errors on their performance in terms of aggregate throughput and fairness.**

I. Introduction

Since the advent of the first IEEE 802.11 standard, much research effort has been spent on improving the performance of its medium access method. This complements the increase in bit rate at the physical layer in the new versions of the standard. Usually, to estimate the improvement, modified access methods are compared under ideal channel conditions. In this paper, we present an evaluation of different access methods in presence of transmission errors. To study their effect on performance, we vary the *Bit Error Ratio* (BER) that influences frame losses. In this way, we can propose a more accurate evaluation in a realistic wireless environment featuring non-ideal channel conditions. To the best of our knowledge, this study is the first evaluation of access methods in presence of transmission errors.

The paper is organized as follows. Section II presents the operation principles of chosen access methods. We then analyze and compare their performance under non-ideal channel conditions in Section III. Finally, Section IV summarizes the results and provides some conclusions.

II. Wireless LAN Access Methods

To perform our study, we have considered four wireless LAN access methods: the IEEE 802.11 *Distributed Coordination Function* (DCF) [1], the *Slow Decrease* method [2], the *Asymptotically Optimal Backoff* (AOB) [3], and the *Idle Sense* mechanism [4]. The basic principles of the last three methods are similar to those of the IEEE 802.11 DCF. The *Slow Decrease* method consists of dividing the contention window (*CW*) by 2 after a successful transmission, instead of resetting it to the minimum value CW_{min}. In *AOB*, each station observes the number of slots in the backoff interval in which one or more stations attempt transmission and the total number of slots available for transmission in the backoff interval. In this way, each station is able to obtain the utilization rate of the slots observed on the channel (*Slot Utilization*). Each station computes the *Probability of Transmission* that depends on the *Slot Utilization* and evaluates the opportunity of either attempt or defer a scheduled transmission. If the transmission is rescheduled, a new backoff interval is computed as if a collision had occurred. We can observe that *Slow Decrease* and *AOB* preserve the exponential backoff mechanism of the IEEE 802.11 DCF when a collision or a frame loss occurs.

Finally, in the *Idle Sense* method, each host estimates the number of consecutive idle slots between two transmission attempts and uses it to adjust its *CW* to the optimal value by means of the *Additive Increase Multiplicative Decrease* (AIMD) principle. The *Idle Sense* proposal goes further beyond the IEEE 802.11 DCF: contending hosts do not perform the exponential backoff algorithm after failed transmissions, rather they make the contention windows dynamically converge in a fully distributed way to similar values solely by tracking the number of idle slots between transmissions.

The last three methods improve the performance of the IEEE 802.11 DCF. They work in a fully distributed way and do not require an estimation of the number of active hosts, which distinguish them from other proposals that we have not considered in this study [5], [6].

III. System Performance

We have chosen the physical layer of the IEEE 802.11g standard for this study. We consider a scenario involving one infrastructure *Basic Service Set* (BSS). To study the effect of transmission errors on performance, we vary the number of stations in the cell and the *BER* values. We compute the *Frame Error Ratio* (FER) as explained elsewhere [7]. To perform our evaluation, we have developed a discrete-event simulator that implements the standard IEEE 802.11 DCF method and all other considered access methods for different parameters of the physical

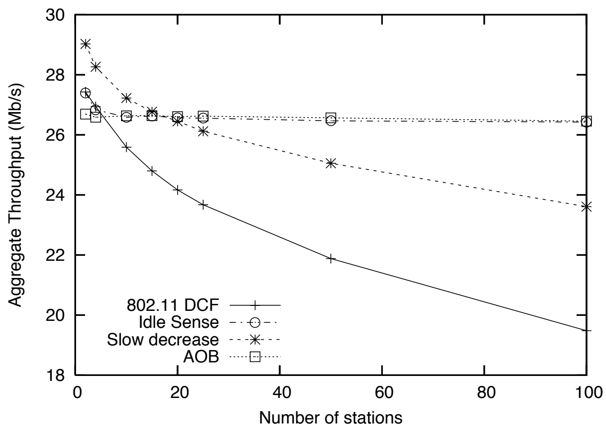

Fig. 1. Aggregate throughput vs. number of stations, $BER = 10^{-5}$

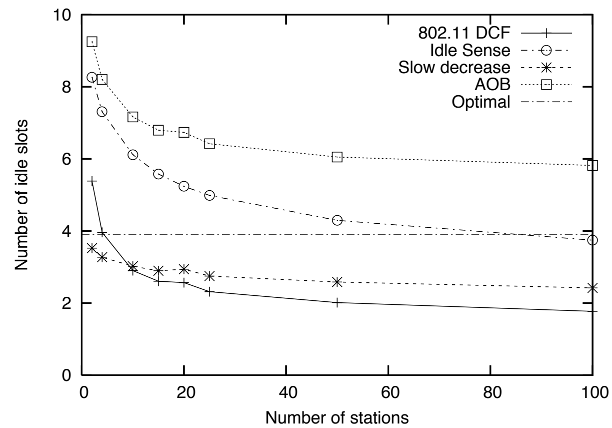

Fig. 2. Average number of consecutive idle slots between two transmission attempts, $BER = 10^{-5}$

layer[1].

In the first experiment, we have considered that every station in the BSS is subject to the same *BER* and consequently the same *FER*. The stations transmit at the highest available data rate (54 Mbps) and send data frames with the maximum size used in practice: the Ethernet MTU of 1500 bytes. We consider the case of greedy hosts: they always have a frame ready to be transmitted. We evaluate and compare the aggregate system throughput for the different access methods.

Figure 1 presents the throughput performance for a cell with $BER = 10^{-5}$ $(FER_{DATA} = 12\%, FER_{ACK} = 0.65\%)$. It shows that *AOB* and *Idle Sense* provide a significant improvement of the throughput performance for a number of stations in the BSS higher than 4 in comparison to the IEEE 802.11 DCF and the *Slow Decrease* method. For a small number of stations and such channel conditions, IEEE 802.11 DCF and *Slow Decrease* perform slightly better, but at the cost of fairness—see below.

Figure 2 shows the average number of consecutive idle slots between two transmission attempts, denoted by n_i, for the different access methods. For a number of stations lower or equal to 4, n_i values for IEEE 802.11 DCF and *Slow Decrease* are closer to the optimal (3.91 for IEEE 802.11g [4]). Then, for an increasing number of hosts *Idle Sense* proposal achieves a n_i closer to the target value, even in comparison with *AOB* mechanism. Stations working under *AOB* perform the exponential backoff after frames losses, and this fact deals to an increase in n_i values.

Moreover, we evaluate the system fairness by using the *Jain fairness index* [8]. We can see from Figure 3 that *Idle Sense* provides better fairness than IEEE 802.11 DCF and the other two modification proposals. While *AOB* and *Idle Sense* present similar good level of throughput for these transmission conditions ($BER = 10^{-5}$), Figure 3 shows that *Idle Sense* provides much better fairness than *AOB*.

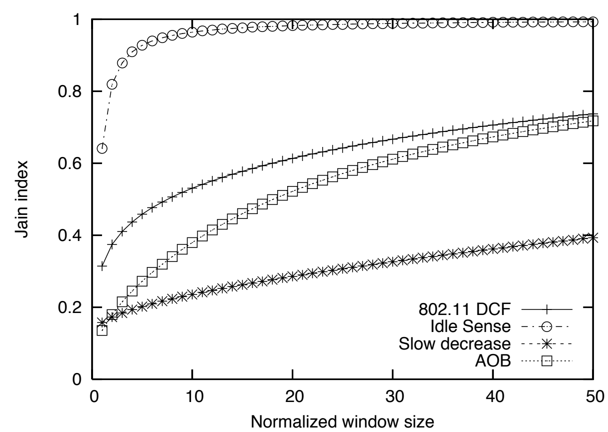

Fig. 3. Fairness comparison for 25 competing stations, $BER = 10^{-5}$

In the second experiment, we consider much higher error rates: $BER = 10^{-4}$ $(FER_{DATA} = 72\%, FER_{ACK} = 6.4\%)$. Figure 4 presents the throughput performance, which is radically different from Figure 1: *Idle Sense* achieves the best overall performance with a throughput gain of 60.3% for 4 stations and of 3.6% for 20 stations with respect to the IEEE 802.11 DCF results. *Slow Decrease* and *AOB* methods do not improve the performance of IEEE 802.11 DCF under such channel conditions.

Better throughput performance of the *Idle Sense* method can be explained by the fact that contending hosts do not perform the exponential backoff. Figure 5 shows n_i values for the different access methods and $BER = 10^{-4}$. We can observe that n_i values for *Idle Sense* remain closer to the optimal value. The other access methods perform the exponential backoff after collisions or frames losses. As the error rate increases, the backoff procedure

[1]We use $CW_{min} = 8$ and $CW_{max} = 1024$ for simulations of *Slow Decrease* ([2] states that a small initial contention window value achieves higher throughput gain); $CW_{min} = 16$ and $CW_{max} = 1024$ are the values for the IEEE 802.11g physical layer, we use them for IEEE 802.11 DCF and *AOB*, and as initial values for *Idle Sense* simulations.

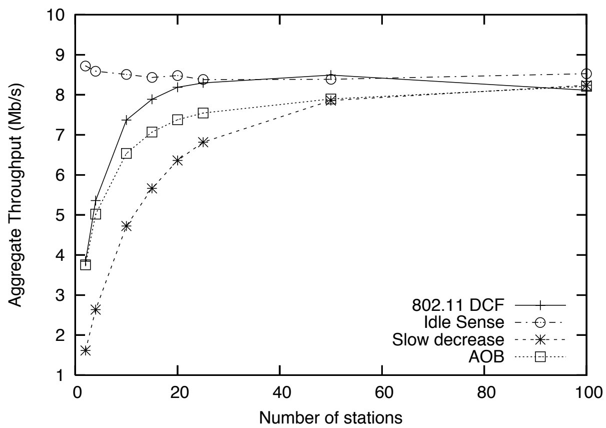

Fig. 4. Aggregate throughput vs. number of stations, $BER = 10^{-4}$

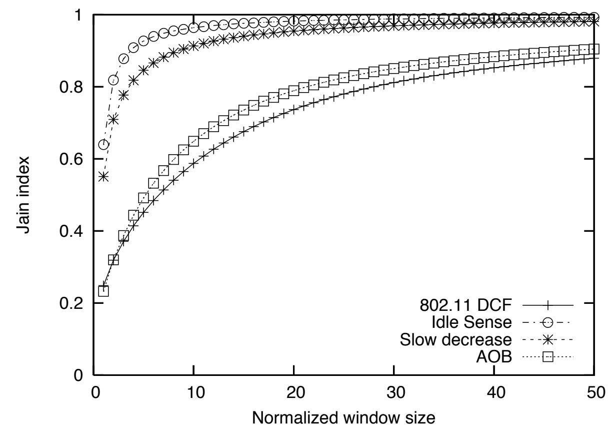

Fig. 6. Fairness comparison for 25 competing stations, $BER = 10^{-4}$

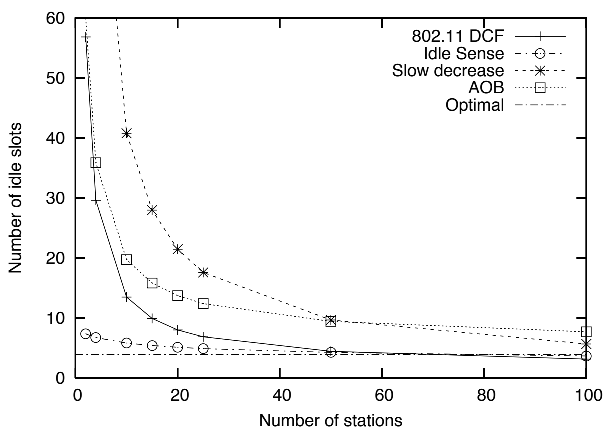

Fig. 5. Average number of consecutive idle slots between two transmission attempts, $BER = 10^{-4}$

results in n_i remaining far from the optimal value. Finally, as the number of stations in the cell increases, the differences between the throughput of access methods are reduced, because n_i becomes closer to the optimal value for such channel conditions.

As above, we also evaluate the system fairness for the higher error rate. We can see from Figure 6 that *Idle Sense* provides better fairness than the other access methods. Moreover, we can observe that *Slow Decrease* improves its fairness, because under such channel conditions the values of *CW* for different hosts are less disproportionate.

IV. Conclusions

In this paper, we present an evaluation of chosen wireless LAN access methods with stations subject to various transmission conditions. We observe that their performance in terms of throughput and fairness radically changes when bit error rate increases. For small error rates, *AOB* and *Idle Sense* provide good throughput, but *AOB* fails to achieve good fairness. When error rates increase, only *Idle Sense* provides good throughput and fairness. The main reason is that *Idle Sense* does not use the exponential backoff algorithm. By using the *AIMD* principle to adjust the contention windows of stations, this method achieves n_i values close to the optimal.

This work is a first step in an in-depth evaluation of the wireless LAN access methods in adverse conditions. To extend the evaluation, we plan to consider other scenarios: cells composed of stations subject to different *BER* values, stations working at different transmission rates, and multicell systems cumulating the problem of overlapping cells with adverse transmission conditions.

Acknowledgments

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