An Enhanced Backoff Method used Between Mobiles Moving in Industrial 802.11

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Abstract

The purpose of this study is to discuss the exchanges between mobiles moving in an industrial environment. To reach this study, a simulation approach has been chosen to be used. The selection of relevant propagation model for the selected industrial site is based on several measurements. By adjusting the parameters of the various models, we decided to select the model recommended by the ITU under reference Pr1238 to use for our industrial indoor domain.

The second step is to minimize the exchange time between mobiles within an 802.11 cell. The optimization of this time was carried out by modifying the binary exponential aspect of the Backoff algorithm in order to reduce the access time of the radio medium.

Keywords: *WLAN, IEEE802.11, CSMA/CA, BEB, Propagation model AP.*

1. Introduction

Wireless local area networks (WLANs) are increasingly popular today. WLANs are used for providing network services in places where it is very difficult or too expensive to lay cabling for a wired network. IEEE 802.11, the most popular WLAN standard, specifications are based on the two lowest layers of the OSI model because they integrate both physical and data link components. All 802 networks have both a MAC and a Physical (PHY) component. The MAC is a set of rules to determine how to access the medium and send data (access method in our case), but the details of transmission and reception are left to the PHY such as sensing the wireless channel and determining whether or not it is idle [1] [2]. Wireless networks use radio frequency channels, as their physical medium in a form of electromagnetic radiation, to exchange data.

Standard wireless networks access methods, especially DCF (Distributed Coordination Function), face some problems related to the transmission priority of different nodes after a success or a fail transmission, these problems cause additional delay [11] [12].

In addition, propagation of radio waves between several nodes moving in the same cell obeys complex rules, especially when there are obstacles between the transmitter and the receiver. A wave can follow several paths to arrive at a common point, so that the receiver can receive multiple copies of the same signal at different instants [3]. The propagation models differ from environment to others, such as industries, universities, home, etc.

Our objective in this study is focused on minimizing the delay of exchanging real-time data between mobiles moving in the same 802.11 cell in industrial domain.

A simulation for several propagation models is performed in NS2 to compare their results to that of the measurement results in the real environment [13].

The rest of the paper is organized as follows: in section 2, we have to pick out the appropriate propagation model for the actual environment. The basic access method DCF is presented in section 3. Section 4 gives an explanation of the enhanced DCF method. In section 5 states the results of the simulations and validation of propagation models. Further, section 6 illustrates the simulations of the enhanced industrial Backoff method and the comparison with the basic method. Finally, section 7 highlights our conclusion and outlines future works.

2. Propagation Models

In this section, we present some existing propagation models in the literature and their characteristics. Also, we focused on the "path loss" of each model.
The "path loss" or power dispersion is characterized by the suffered attenuation when an electromagnetic wave traverses a distance. This weakness is mainly due to the dispersion of power and the path obstacles of each received signal component (for example buildings, mountains are signal blockers).

2.1 Free space model

This model only assumes the direct path between transmitter and receiver. Eq. (1) represents the received power P_r.

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \quad (1)$$

With P_t is the transmitted power, G_t and G_r are respectively the gain of the receiver and transmitter antenna, d is the distance between both nodes and L is the system loss coefficient [3].

2.2 Two-ray ground reflection model

The two-ray ground reflection model considers both the direct path and the ground reflection path. The received power at distance d is represented by Eq. (2).

$$P_r(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4 L} \quad (2)$$

Where h_t and h_r are respectively the heights of transmit and receive antennas.
The two-ray model does not give a good result for a short distance due to the oscillation caused by the constructive and destructive combination of the two rays [4].

2.3 Log-distance path loss model

The log-distance path loss model is a propagation model that takes into account the different obstacles present in multiple transmitter-receiver paths with the same separation. This model predicts the received signal strength between clients and access points [5].
The log-distance path loss model is given by Eq. (3) [6].

$$L_{total} = PL(d_0) + N.\log_{10}(d/d_0) + X_s \quad (3)$$

Note that:
- *Ltotal* is expressed in decibel,
- *PL(d0)* is the path loss at the reference distance, usually taken as (theoretical) free-space loss at 1m,
- *N/10* is the path loss distance exponent,
- *Xs* is a Gaussian random variable with a mean of zero and a standard deviation of σ dB.

2.4 ITU-R P.1238-4

"ITU-R P.1238-4" deals with data propagation and prediction methods for indoor radio systems and radio local area networks in the frequency range from 900 MHz to 100 GHz. As the propagation conditions will vary from one site to another, therefore we should refer to any kind of average site.
The attenuation (power dispersion) is given by Eq. (4).

$$L_{total} = 20\log f + N\log_{10} d + Lf(n) - 28dB \quad (4)$$

With:
- N represents the coefficient of attenuation,
- f is the frequency in *MHz*,
- d is the distance in *meter*,
- Lf is the attenuation factor,
- n is the number of floors,
- and σ is the standard deviation.

Note that n and N differ by a factor of 10, as well as in "Free space" model n is equal to 2 and N is equal to 20 [7].

3. Access methods

A station must first gain access to a shared radio channel before transmitting a frame. In 802.11 Standard, two forms of medium access are defined: first one which is mandatory called the Distributed Coordination Function (DCF), and the second one is optional known as Point Coordination Function (PCF) which is only usable on infrastructure network configurations [8]. When applying a PCF method, a Point Coordinator (PC) resides at the Access Point of the Basic Service Set (BSS) and controls frame transfers during a Contention Free Period (CFP) to determine which STA has the right to transmit at the current instant by performing the role of the polling master. The PC controls the frame transmissions of the STAs to eliminate contention for a limited period of time [8]. Our work focuses only on DCF since the infrastructure BSS is used in our environment.
Distribution Coordination Function (DCF) is the fundamental access method of the IEEE 802.11 protocol which is also known as *carrier sense multiple access with collision avoidance* (CSMA/CA). DCF allows for the automatic medium sharing between compatible PHYs through the use of CSMA/CA and a random backoff time following a busy medium condition **[**8**].** Before initiating a transmission, the station senses the medium, if it is idle throughout an interval of time equal to Distributed InterFrame Space (DIFS), the transmission will progress; otherwise it defers until the ongoing transmission terminates and the medium maintains to be idle for a period equal to DIFS, than the station generates a random backoff interval to reduce the probability of collision with

other stations that are also transmitting frames *or* those that are trying to access the same channel.
The DCF implements a slotted binary exponential backoff; when a station finds the medium busy or when it fails to transmit data, it selects a random backoff time. This guarantees that the stations seeking for the channel don't transmit simultaneously. The station sets the Backoff timer using Eq. (5).

$$\text{Backoff Time Random}( ) * \text{SlotTime} \qquad (5)$$

Where *Random()* returns a random integer within the range *[0,CW]*.
The random delay causes stations to wait different periods of time and prevents them from sensing the medium together at exactly the same instant, finding the channel idle, transmitting, and colliding with each other **[**9**]**. *CW* (Contention Window) is the total time that a source station waits before sending frames, and it's constrained between $CW_{min} \leq CW \leq CW_{max}$, CW_{min} is the initial parameter of *CW* at the first transmission. After each unsuccessful attempt to transmit, *CW* increments double its previous value (2* *CW*) till it reaches its maximum value CW_{max}, and it resets to CW_{min} after each successful transmission.
The highest probability for a collision to occur is when multiple stations contend to access an idle channel after it was busy with another station. Here, the backoff procedure is required to avoid the collision, and the station that has the lowest backoff time has the priority to access the channel which consequently decreases the delay of transmission time and optimizes the throughput. If the station fails in transmission, it resets the backoff timer to a new random number and counts down again; CW gets larger as frames fail in transmission $CW = CW * 2^n$. Where *n* is the number of collisions [10].

Some frames fail to reach the destination more than once; therefore the source keeps retransmitting them till these frames reach their destination successfully. Errors that occur, due to a collision between frames or to transmitting either data frame or ACK frame, cause delay in time and lower performance in throughput. These effects are caused by the recovery procedures of the effected frames while exchanged between stations. Additionally, increasing the number of mobiles that are contending on the shared channel ends up with lower performance too.
There are two possible cases in the basic DCF access method: First case is when a collision occurs; the priority to access the channel will be given to one of the remaining contending stations based on its smaller backoff time interval, as mentioned before. This causes the collided frame to delay in transmitting and makes it waits more, since its *CW* is doubling-up.
The second case is when a transmission successes; therefore, *CW* for the transmitting station is equal to CW_{min}, as long as it is transmitting successfully, which keeps the priority to this station to access the channel, while on the other side a delay on transmission will arise for the other contending stations.
Based on those two cases, we observe that there are some disadvantages of using IEEE 802.11 DCF scheme, because it suffers a fairness problem [11] [12]. That means that the nodes with smaller *CW* have more chances to get access to the medium, and after a successful transmission the priority to access the medium raises. This issue affects the performance of the CSMA/CA protocol and causes a delay in time.
The Mealy graph shown in Fig. 1, represents the mechanism of BEB.

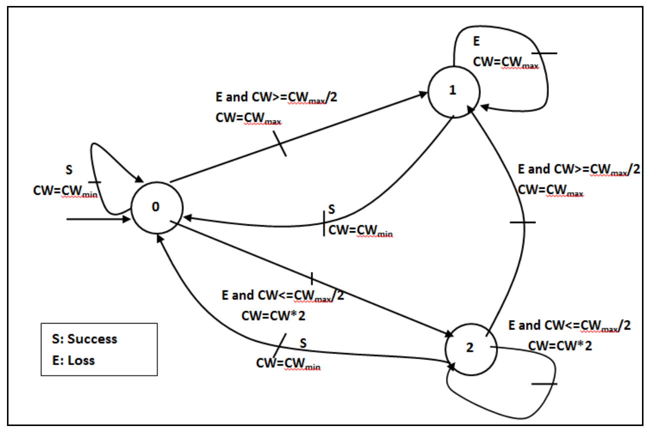

Fig. 1 Mealy graph represents the mechanism of BEB

4. Proposed method

This section focuses on an enhanced method of the basic DCF purposed for decreasing the delays that happened in either of the mentioned issues in cases of collision or successful transmission.
This issue is treated by changing the way that *CW* will be set in the two cases:
Firstly when a collision occurs, instead of multiplying *CW* by 2, it is multiplied by ***a*,**
Where $0 < a < 2$, thus $CW = CW * a$**.**
Secondly when a frame is successfully transmitted, instead of keeping *CW* of the successful transmitted station equals to CW_{min}, we assume that *CW* decreases by *b*, where $0<b<2$, thus $CW = CW - b$.
The following Mealy graph represents the modified BEB method.
The Mealy graph shown in Fig. 2, represents the modified BEB.

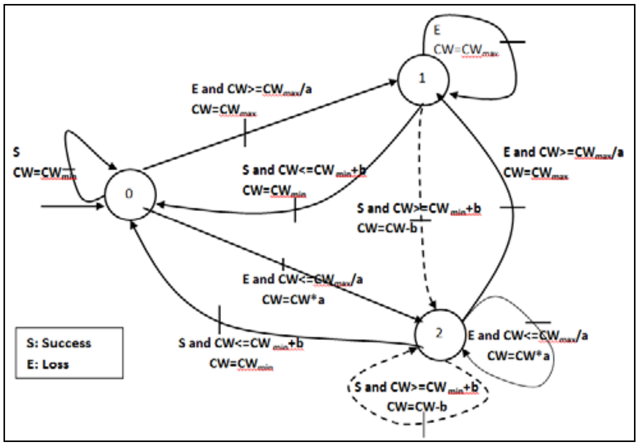

Fig. 2 Mealy graph represents the modified BEB method

5. Simulations and validation of propagation model

5.1 Selection of the propagation model

In order to minimize the transmission cycle between mobiles, we need to choose the best access method; for that a simulation for several propagation models is performed in a previous work [13], to compare their results to that of the measurement results in the real environment. This comparison shows that the ITU model is the best model that gives propinquity between simulations results and the measurement results.

5.2 Implementation of the ITU1238 model

In NS2 [14] [15], the default model used is the "Free space". It expresses the form of the Path Loss Relationship between the received power P_r and the transmitted power P_t, this relationship is given by Eq. (1).
To assure that the ITU model matches our work environment, we modify the "Free space" model by replacing Eq. (1) by the equation of the ITU1238 model mentioned in Eq. (4).

5.3 Validation of the propagation model

To validate the propagation model (ITU1238), we must compare the simulation results with the power measurements done on the site.
The objective of this simulation is to validate the model implemented in NS2 by comparing the obtained results with P_r measurements on site.

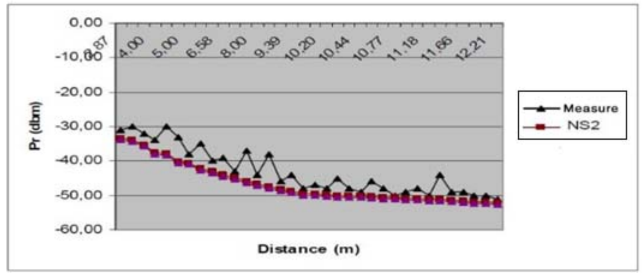

Fig. 3 Results obtained by NS2 and by measurements.

To validate the ITU propagation model, consider the difference between the curve obtained by NS2 and all measurements made on the site. If the difference is approximately equal to zero, thus, we consider that this model is valid and the implementation is realized correctly.
Fig. 3 shows that the average of differences between NS2 results and measurements values is approximately equal to zero.
This propagation model will be used in the next simulations taking into consideration the specific propagation parameters related to the environment.

6. Simulation of the enhanced industrial Backoff method and comparison with the basic method

To increase the performance of BEB, we try to change the values of a and b, where the value of a is set to a fixed number of time slots between 1 and 2. For each fixed value of a**,** the value of b varies between 0 and 2, in aim to find the lowest time delay (msec) at high packet arrival rate. Fig. 4 shows that the optimum values of delay time (approximately about 50 msec) and packet arrival rate (100) is obtained when $a = 1.4$ and $b = 1.2$

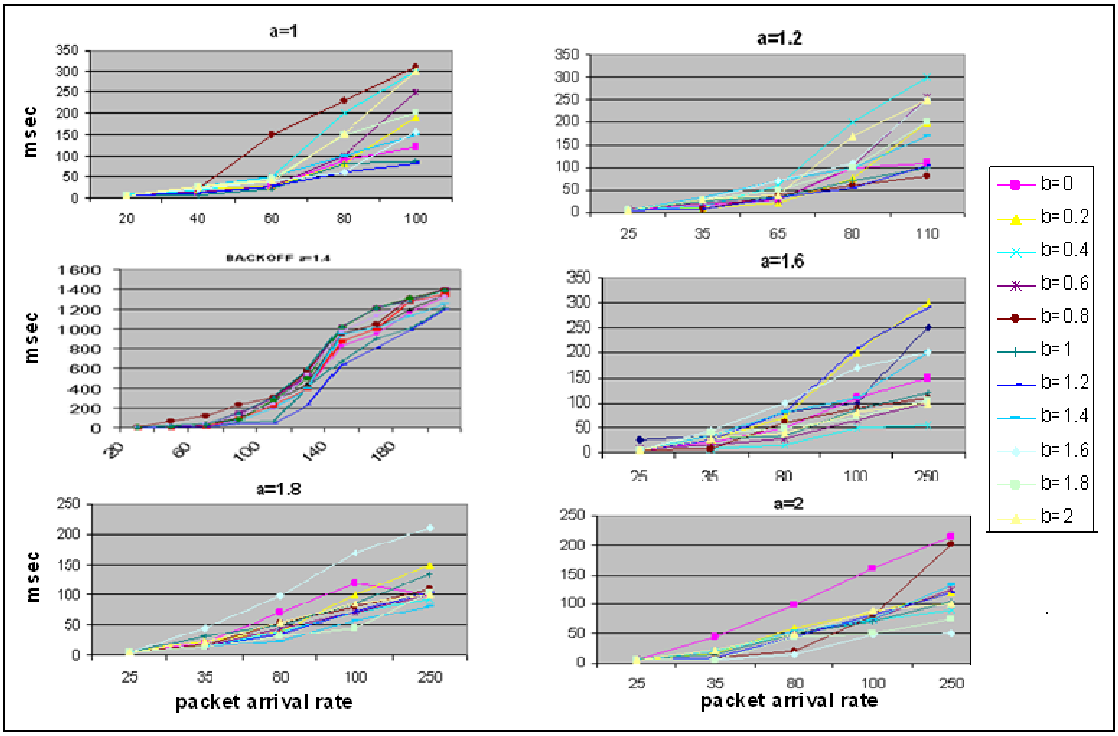

Fig. 4 Results of simulation of modified BEB by varying a and b.

The graph presented in Fig. 5 compares the results obtained by the BEB method and the results obtained by the enhanced method. The transmission time of the enhanced BEB method is less than the one of the BEB method for all values of packet arrival rate.

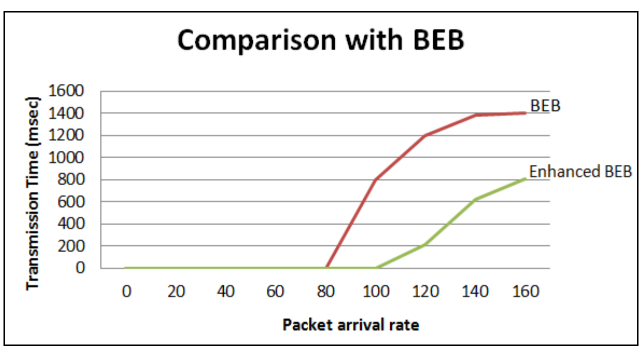

Fig. 5 comparison of the results obtained by the BEB method and the results obtained by the enhanced method

7. Conclusion

In this paper, after comparing the simulation results from NS2 for different propagation models to the real environment measurement results, ITU shows the best performance that fits to our industrial environment (indoor environment). In addition, those parameters of the ITU model have been used in NS2 to make the simulation for the standard and the novel access method which performed better time delay. DCF standard model has some disadvantages when it comes to time delay caused by the collisions or by the alternative success transmissions meaning that the mobiles suffer a fairness problem as mentioned. A new method was proposed in order to decrease the time delay where *CW* is multiplied by **a** instead of 2 when a collision occurs and subtract **b** when a transmission successes. The simulation of this new method shows better performance than the basic method DCF particularly when **a=1.4** and **b=1.2** where the time delay was less than 50 msec at 100 packets arrival.

The future work focus on a novel method that is based on the DCF concept, CSMA/CA, but instead of having $CW*2^n$ as a Backoff time, it will have a **Time Priority,** also instead of the mobile waits a DIFS to start sending data, it will wait AIFS time, with ***SIFS* < *AIFS* < *DIFS***. In this method, a priority is given for each mobile: as its priority increases as the mobile should wait less time. If any mobile (M) wants to send a frame over the network, it should wait a time t_n as it has a priority P_n., where n is the priority number.

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