A COMPARATIVE STUDY OF THE TRADITIONAL MODEL OF IEEE 802.15.4 AND NON-OVERLAPPING BINARY EXPONENTIAL BACKOFF IEEE 802.15.4

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ABSTRACT

This paper introduces a performance model of a recently proposed backoff technique named Non-overlapping binary exponential backoff algorithm over IEEE 802.15.4, which is designed for LR-WPAN. To reduce the collision rate in highly populated wireless networks, non-overlapping binary exponential backoff tries to evenly distribute the random backoff delay by distinguishing the new range of backoff delays. For the performance measurement of non-overlapping binary exponential backoff algorithm, obtained results are compared with the traditional model of IEEE 802.15.4. Our numerical analyses show that non-overlapping binary exponential backoff improves the throughput and transmission delay comparing to the traditional BEB.

KEYWORDS

Binary Exponential back off, Window Size, Contention Windows

I. INTRODUCTION

Algorithm and protocols are the essential tools for the packet networking featuring distribution. A widely used collision resolution protocol is the *binary exponential backoff* (BEB). Its different forms are included in Ethernet [1] and Wireless LAN [2] standards. BEB is a special case of *exponential backoff* (EB).

IEEE 802.15.4 standard has been suitably optimized for Low Rate Wireless Personal Area Network (LR-WPAN) environments characterized by a small number of battery-operated nodes located within a personal area for low-speed communications [3,4,5,6]. This standard provides two operational modes such as CAP(Contention Access Period) and CFP(Contention Free Period) to support both asynchronous and synchronous traffic. Recently diverse backoff algorithms [7,8] have been suggested to improve the performance of BEB of IEEE 802.15.4

To achieve better performance while maintaining the same degree of transmission delays, many new backoff algorithms tries to categorize nodes into some groups which are assigned to separate backoff regions in addition to doubling these ranges. One of them [9] called non-overlapping binay exponential backoff (NO-BEB) exploits the number of successive frame delivery failures to split the backoff range into non-overlapped sub-intervals. In NO-BEB,

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nodes select a random number for their backoff counter from the latter half of the two fold range, namely [2^{BEi-1},2^{BEi}-1] rather than [0, 2^{BEi}-1] at *i-th* failure occurrence.

The NO-BEB accomplishes higher throughput and shorter delay by up to 39% and 16% at maximum, respectively, than the conventional BEB. Also necessity of IEEE 802.15.4 model for NO-BEB is due to fact that IEEE 802.15.4 is significantly differentiated from IEEE 802.11 in terms of three main features such as nonfreezing operation, two channel sensing, and two different channel busy probabilities.[10-11]

First, CAP in IEEE 802.15.4, continues to decrement the randomly chosen backoff delay without carrier sensing to save the listen power dissipation differently from DCF in IEEE 802.11. Second, when the backoff counter reaches zero, CAP performs carrier sensing called CCA(Clear Channel Assessment) twice before transmission. Once the channel is estimated to be busy at either of the two detection times, it doubles the range to select a new backoff delay unless the range exceeds the predetermined maximum.

During process CAP resets its back off counter to the minimum regardless of collision. Finally, the IEEE 802.15.4 model assumes two different busy channel probabilities since the numbers of nodes involved during each CCA time slot are varied. To explore the performance effects of Non Over lapping -BEB algorithm over IEEE 802.15.4, this paper presents a comparative study of throughput and delay related to both the algorithm.

II. The stationary channel state probability

The distribution of the channel states can be derived for each slot. If p is known as the stationary/transition probability P_i , Ps and Pc, respectively that a slot is idle, success and having collision. These probabilities are given by the relations as follows:

$$P_i = (1-p)^n \qquad \ldots (1)$$

$$P_s = n\,p\,(1-p)^{(n-1)} \qquad \ldots (2)$$

$$P_c = 1-(1-p)^n - n\,p\,(1-p)^{(n-1)} \qquad \ldots (3)$$

For the computation purposes we have taken p = 2/(CW+1), where CW is the size of contention window. Symbol n is used for the number of stations.

III. IEEE 802.15.4 performance model

Figure 1 shows a typical two-dimensional Markov chain that models the behavior of IEEE 802.15.4. In this figure the state of each circle consists of two variables *(i, k),* representing the number of backoffs, and the remaining count of the backoff delay, respectively. Symbols α and β stand for the probabilities of detecting busy channels during the first and second clear channel assessment (CCA), respectively. W_i and W_0 represent the maximum number of time slots to wait at the i^{th} backoff stage and the initial stage, respectively.

IV. Non overlapping binay exponential backoff (NO-BEB) PERFORMANCE

Figure 3 presents the discrete time Markov chain model of NO-BEB over IEEE 802.15.4. To distribute waiting times, uniformly, over successively doubled interval, NO-BEB algorithm uses only the latter half of the interval rather than the whole one to avoid overlapping with the previous interval. With this scheme, nodes with different number of unsuccessful channel captures are more likely to be allocated to the non-overlapped regions, leading to the different random backoff delays. Precisely, this algorithm allows nodes to randomly choose a number within the range of [2^{BEi-1}, 2^{BEi}-1] instead of [0, 2^{BEi}-1], where *i* represents the number of consecutive CCA failures.

In figure 3 under saturation condition nodes have data to send all the time. The difference between Figures 2 and 3 is transitions between two adjacent stages. In NO-BEB model, the backoff counter at the i^{th} stage at the unsuccessful capture is set to the one within [W_{i-1} , W_i -1] while the counter in BEB falls into [0 , W_i -1].

The state transition probabilities from the state $b_{j,l}$ to the state $b_{i.k}$ where , where $i \in (0,m)$ and $k \in$ (-1, W_i -1) represents the state probability that the node has the backoff counter with *k* after *i* failures at a given time. Note also that W_i -W_{i-1} denotes the size of a given backoff range at the i^{th} stage. The differences between NOBEB and BEB is given in [9] for more details. It is important to note that is the probability of detecting the busy channel at either the first or second CCA time.

Symbol τ shows the probability that a given node attempts the first CCA. It is represented by the sum of the probabilities of the states at the first column in figure 2. Meanings of the other symbols are as follows; n is the number of competing nodes. L denotes a frame's transmission delay.

$$\tau = \frac{\left[\frac{1-p^{m+1}}{1-p}\right]}{\left[\left(\frac{3}{2}-\alpha\right)\frac{1-p^{m+1}}{1-p}+\left(\frac{3W0}{4}\right)\frac{1-(2p)^{m+1}}{1-(2p)}\right]} \quad \dots (4)$$

From the next step α and β are obtained employing relations mentioned in [ ]

as follows:

$$\alpha = \left[l(1-(1-\tau)^{n-1}) + n\tau(1-\tau)^{n-1}\right](1-\alpha)(1-\beta) \quad \dots (5)$$

$$\beta = \frac{1-(1-\tau)^{n-1}}{2-(1-\tau)^{n}} \quad \dots (6)$$

The saturation throughput of IEEE 802.15.4 is given as

$$S = (Coeff)P_{transmit}\ P_{success} \quad \dots (7)$$

Coeff is the ratio of payload length in slots to the average length of a slot time.

$P_{transmit}$ represents the probability that at least one node transmits ion a given slot time. This implies that $P_{transmit}$ denotes the probability that one node does not attempt to send a frame and at the same time channel is idle at the two CCA. It is calculated using relation

$$P_{transmit} = (1-(1-\tau)^{n})(1-\alpha)(1-\beta) \quad \dots (8)$$

$P_{success}$ is the probability that only one node transmits on the channel and the other n-1 nodes do not transmit. It is calculated using following relation

$$P_{success} = \frac{n\tau(1-\tau)^{n-1}(1-\alpha)(1-\beta)}{P_{transmit}} \quad \ldots (9)$$

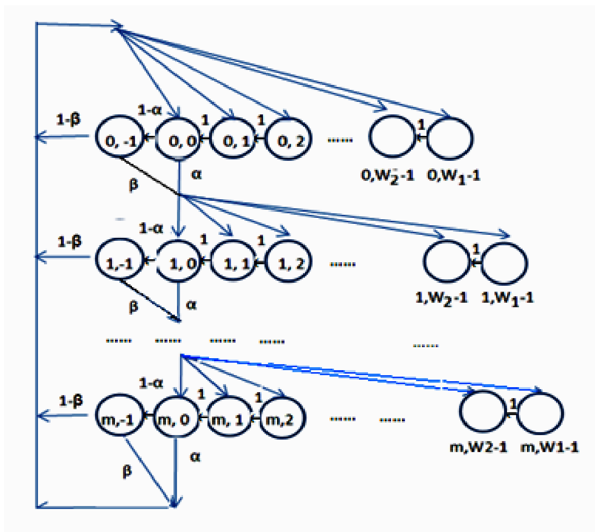

Figure 1. Discrete time Markov chain model for an IEEE 802.15.4 network

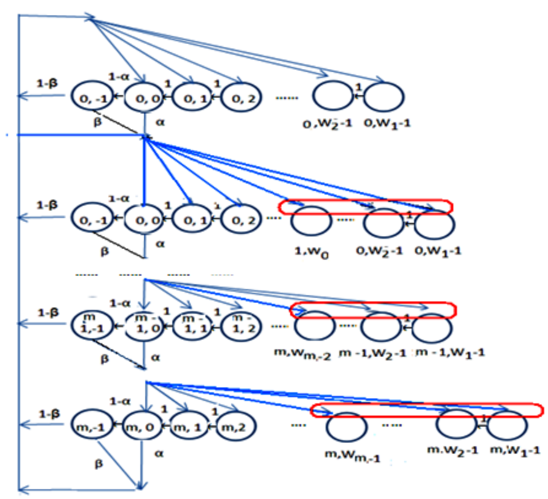

Figure 2. Discrete time Markov chain Model for NO-BEB algorithm. Red portion shows NO-BEB

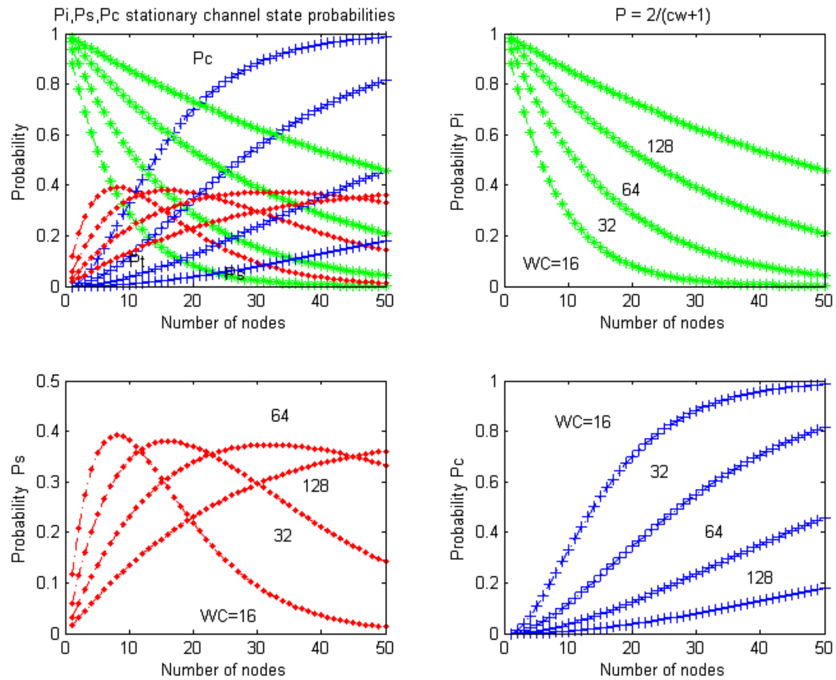

Figure 3. *Numerical results of stationary probability that a slot is idle, success or collision versus number of nodes. (a) all three types of plots; (b) probability P_i as a function of nodes; (c) probability P_s as a function of nodes* and (d) *probability P_c as a function of nodes.*

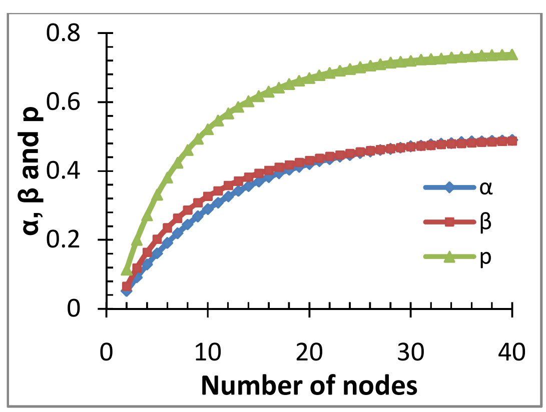

Figure 4. *Variation in α, β and transition probability p as a function of the number of nodes*

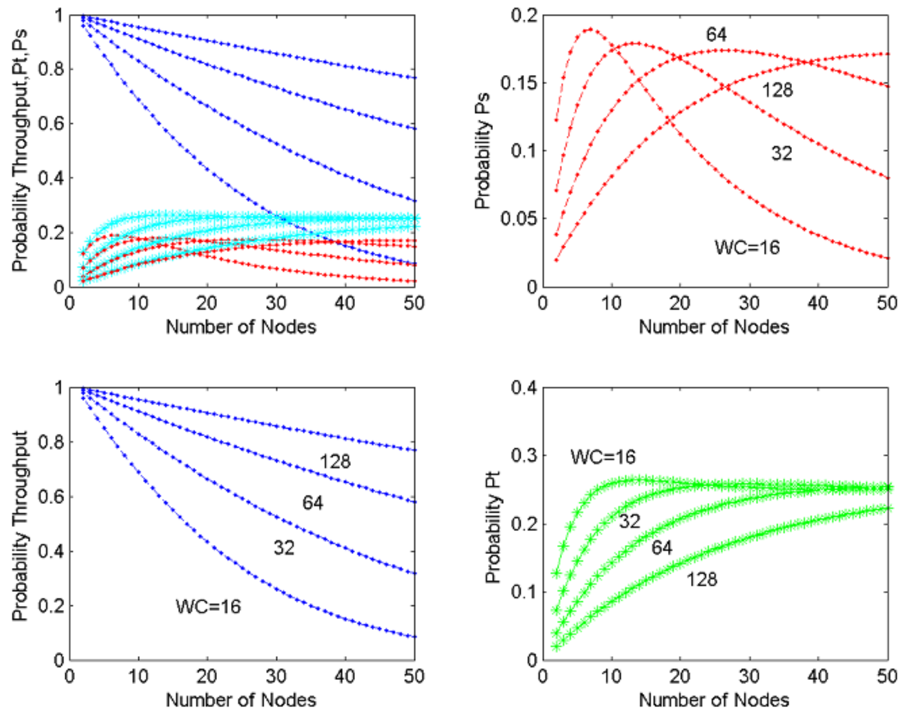

Figure 5. *Results of non overlapping binay exponential backoff probability throughput, probability of success and probability of transmit as a function of nodes.*

V. Simulations and results

Graphical plots of the results obtained using equations (1), (2) and (3) are shown in figure 3. Figure 3(a) shows stationary probability of idle, success and collision as a function of numbers of nodes. Figure 3(b) shows stationary probability that a slot is idle against number of nodes. For the lower values of windows size, i.e. WC=16 P_i becomes asymptotic corresponding to the number of nodes 30. With the increase in window size P_i attains asymptotic character at higher number of the nodes. Similarly stationary probability of success and collision versus number of nodes are shown, respectively, in figures 3(c) and 3(d). The maximum probability of success is independent of the window size but the maxima of P_s shifted towards increasing number of nodes. For a fixed number of nodes the probability of collision decreases with the increase in window size.

Equations (4)-(9) are related to the non-overlapping binary exponential back off algorithm. Symbol τ shows the probability that a given node attempts the first CCA. It is computed using equation (4). Required variables in this equations are set initial value within the programme. After obtaining the value of τ, the magnitude of α and β are obtained employing equations (5) and (6).

Knowing the values of τ, α and β the probability that one node does not attempt to send a frame that is, $P_{transmit}$ is calculated using equation (8). Also the values of

$P_{success}$, which is the probability that only one node transmits on the channel and the other n-1 nodes do not transmit is obtained using relation (9). In the last The saturation throughput of IEEE 802.15.4 is obtained using relation (7).

Figure 4 displays variation in α, β and transition probability p as a function of the number of nodes. From the plots it is evident that all three variables increases with the increase in number of nodes. The values of *in α and β coincide with each other after number of nodes n=20.*

Obtained probability of success, transmit and throughput versus number of nodes for four different values of window size are given in figure 5. The initial values of m, L, α, β and number of nodes were set to 10, 5, 0.8 and 0.5, respectively. From the figure 5 following conclusions are drawn:

(a) The peak of probability P_s shifted towards increasing side of the number of nodes.

(b) The peak height of P_s is almost independent of window size.

(c) The probability of success becomes widen in compassion to the plots shown in figure (3)

(d) The probability of transmit obtains asymptotic value for lower values of window size.

(e) The probability of transmit increases with the increase in number of nodes.

(f) The probability throughput increases with the increase in window size.

(g) The probability throughput decrease with the increase in number of node.

CONCLUSIONS

The numerical result of the graphs in figure 3. And the final outcome in figure 5. Results of backoff probability throughput, is been finally calculated which is been taken from References(8). Future Work to demolish the collision with the help of suggested equation and create a perfect wireless network.

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