PRESENTATION 12

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Performance Analysis of 802.11 DCF MAC

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Introduction

Recently the so-called Wi-Fi technology has received a lot of researchers' attention since it is the most commonly used for wireless LANs. The behaviour of the 802.11 WLAN was investigated under various scenarios mainly by means of simulations. However it was observed that even the most used network simulator NS-2 greatly underestimates the saturation throughput [5].

Bianchi [1] have introduced markovian model which has made possible appropriate describing the backoff procedure used by distributed access mechanism. Several simplifying assumptions are used in this model and constrain its application. Later the enhancements of this model (mainly concerned the fine points of the standard) have been made in [3, 4, 5, 6].

The fragments of the original chain are shown in the Figure (1). It represents the bidimensional backoff process. Here the first index is the the number of consecutive collisions (backoff stage) and the second one is the backoff counter. Abide by [5], denote by P_{tr} the probability that there is at least one transmission in the slot time. Let P_c be the probability that a transmitted packet collides.

The idea of our work is based on the fact that the backoff process is continuous-time one and markovian process can be applied if and only if the sojourn times either are equal to each other or are exponentially distributed (the memoryless effect takes place). However, any of conditions is not executed.

Therefore we adopt the so-called semi-markov process to describe the backoff procedure. Random variables which make sense of time spent at the state before next transition are specified on the transitions of the initial Markov chain. Estimating the expectations of the sojourn times we can adjust the stationary probabilities of being at the certain state of initial chain.

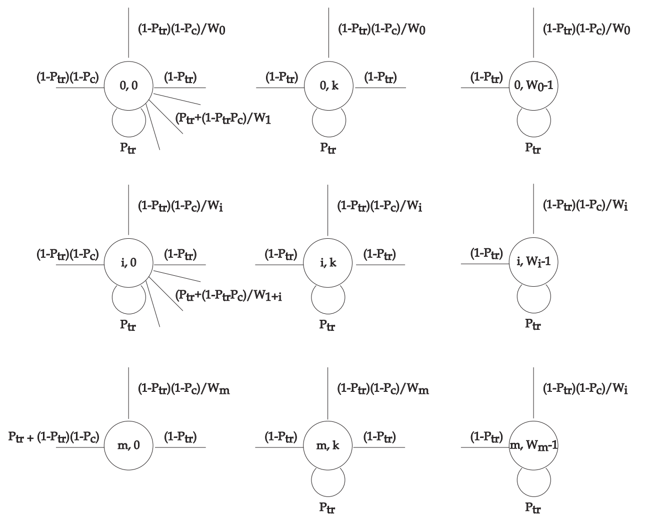

Figure 1: Initial markovian model of 802.11 backoff

Semi-markov model

The transition probabilities of the Markov chain are:

$$\begin{cases} P\{i,k|i,k+1\} = 1-P_{tr} & k\in(0,W_i-2) \quad i\in(0,m) \\ P\{i,k|i,k\} = P_{tr} & k\in(1,W_i-1) \quad i\in(0,m) \\ P\{0,k|i,0\} = (1-P_c)(1-P_{tr})/W_0 & k\in(0,W_0-1) \quad i\in(0,m-1) \\ P\{i,k|i-1,0\} = P_{tr}+(1-P_cP_{tr})/W_i & k\in(1,W_i-1) \quad i\in(0,m) \\ P\{0,k|m,0\} = 1/W_0 & k\in(0,W_0-1) \end{cases} \qquad (1)$$

The process is ergodic and there exist the stationary distribution:
$b_{i,k} = \lim_{t\to\infty}(P\{s(t)=i,b(t)=k\}, i\in(0,m), k\in(0,W_i-1))$

Denote by τ_M the probability of transmission attempt and let p_M be the probability of unsuccessful attempt. Then the analysis if the chain leads to the non-linear system of equations:

$$\tau_M = \frac{2(1-2p_M)(1-p_M^{m+1})}{W(1-(2p_M)^{m+1})(1-p_M)+(1-p_M^{m+1})(1-2p_M)} \qquad (2)$$

$$p_M = 1-(1-\tau_M)^{2n-1} \qquad (3)$$

Let $h_{i,k}$ be the expected time of being at the state (i,k) before transition. Then the the stationary probabilities of the semi-markov process are

$$f_{i,k} = \frac{b_{i,k}h_{i,k}}{\sum_t^m \sum l^{W_i-1} b_{t,l}h_{t,l}} \qquad (4)$$

Let E_b be the expected length of the period when the station sences the channel busy but associated backoff counter is not equal to zero. Denote by E_i the expected length of the idle slot. And let E_t be the expected length of time interval when the station participates in transmission.

Then we can write

$$\tau = \sum_{i=0}^{m} f_{i,0} = \frac{\tau E_b+(1-\tau)E_i}{\sum_{t=0}^{m}\sum_{l=1}^{W_i-1} b_{t,l}(E_b+(1-\tau)E_i)+\sum_{t=0}^{m} b_{t,0}E_t}\sum_{i=0}^{m} b_{i,0} \qquad (5)$$

After some calculations (5) can be rewritten as

$$\tau = \frac{\tau E_b+(1-\tau)E_i}{(1-\tau_M)(\tau E_b+(1-\tau)E_i)+\tau_M E_t}\tau_M \qquad (6)$$

Analysis of the last equation shows that $\tau >> \tau_M$. This allows us to conclude that the actual transmission probability is greater than the probability evaluated from the analysis of the initial Markov chain. Therefore the performance of the network looks more optimistic.

From the value for τ we can deduce the expression for normalized throughput. In the Figures (2) and (3) the throughput calculated on the base of semi-markov model was visualized for two different access methods and compared with earlier models and simulation results.

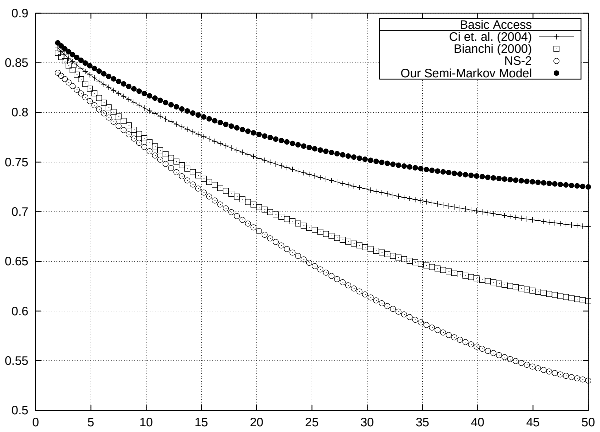

Figure 2: Saturation Throughput for Basic Access Method

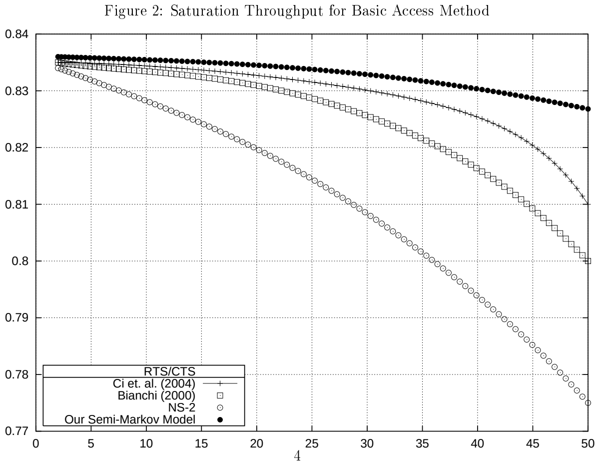

Figure 3: Saturation Throughput for RTS/CTS Access Method

Conclusions and Future Work

In this work the more accurate semi-markov model for the IEEE 802.11 DCF MAC was constructed. In this model the distribution of time interval lengths before transition to the next backoff state is taken into account. The other enhancements of the initial Bianchi's model which are described in [4], [5], [6] are given proper weigh as well.

The results show that Wi-Fi LANs provide better performance than it was supposed and than it was estimated earlier. It can be explained with the fact that the existing models don't take into account that on average the station spends more time in the "transmission" state as compared with a time in "waiting" one. From the results of throughput evaluation we can conclude also that the RTS/CTS access method demonstrates more stable behaviour than the basic one.

In the future we'll try to find the optimal or quasioptimal distribution of frame lengths which would provide the better performances of WLAN. We'll also try to extend obtained results to the more wide class of backoff algorithms for the purpose of finding the most suitable ones. In particular we intend to compare the performances of various implementations of BEB, EIED, EILD, MILD and others.

We are about to investigate the behaviour of 802.11 WLAN on some special conditions such as the presence of different kinds of noise and the presence of signal propagation barriers.

References

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