

Evaluation of the Wireless IEEE 802.11 MAC Protocol Under Poisson Background

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Abstract

Wireless access using the IEEE 802.11 MAC protocol have had a wide deployment in recent years. In this report we investigate the influence of this protocol in terms of response times, packet losses and playout for different packet sizes. We consider a CBR stream sharing the wireless media with Poisson background. The numerical results of the IEEE 802.11 have been obtained using the network simulation (ns), which offers a detailed implementation of the DCF access procedure using RTS/CTS. Simulation results are compared with an M/D/1 queue.

1 Introduction

The IEEE 802.11 standard [6] defines layer 1 and 2 for WLANs. This standard has had an huge acceptance and deployment in recent years. In this report we analyze the impact of the 802.11 MAC protocol. The standard defines two access procedures: the Distributed Coordination Function (DCF) and an optional Point Coordination Function (PCF). DCF is intended to efficiently support a best effort service based on the CSMA/CA distributed algorithm. This method is optimized by a *virtual carrier-sense* algorithm based on a reservation mechanism carried out by RTS/CTS frames. The optional PCF access mechanism is a pooling system build up over DCF. PCF allows for a contention-free access, thus, is intended for real-time applications having delay constrains.

In this paper we focus on the DCF access procedure. We have used Poisson background because is the background of choice in many analytical models. In fact, this work was motivated in order to have some preliminary results before an analytical approach. We have tried to use simple parameters in order to have results easy to understand.

There are other performance evaluation studies of this protocol in literature. In [3] and [4] the authors analyze the protocol by simulation. In order to have a realistic scenario the authors use frames of variable length and introduce transmission errors. Several analytical studies can be found. E.g. in [7] the authors analyze the hidden terminal problem, [9] performs a capacity analysis and [2] presents a Markov chain to investigate the throughput varying several parameters of the access protocol. In [8] the authors investigate the 802.11 handoffs experimentally and other papers e.g. [5] investigate the QoS support.

2 Simulation Framework

The network topology consists of three Mobile Nodes: AP, MN and BG (see Figure 1). The wireless media is 802.11 with DCF access procedure using RTS/CTS (see [6]).

We are interested in evaluating a CBR stream sent from AP towards MN. The background consists of packets generated at exponentially distributed instants (Poisson background). Background packets

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are generated in both directions between AP and BG. All packets (CBR and background) have the same length.

This scenario tries to model the effect of multiplexing a CBR stream at an IEEE 802.11 access point (AP). The background sent from AP to BG would model the packets sent from the AP to other MNs. The background sent from BG would model the packets sent from other MNs towards the AP.

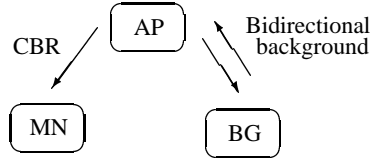


Figure 1: Network topology.

3 Numerical Results

The results have been obtained with the ns simulator [1]. We have used the following simulation parameters:

- Wireless transmission rate: 2 Mbps.
- CBR rate: 64 kbps.
- Queue length: 200 frames at network interfaces.

Several simulations have been carried out using different packet sizes. In each simulation all packets (CBR and background) have the same size. Each simulation has been run for 200 seconds, leaving out the initial 25% in the evaluations (as transient).

In order to have a pictorial view of the simulations, figure 2 shows 20 seconds of traces corresponding to two different simulations. The y-axis gives the response time of CBR packets in slots (we define the *response time* as the difference between the reception and generation time of the packet by the receiving and sending agents respectively, and a *slot* as the transmission time of one packet at the link rate). The x-axis correspond to the generation time of each CBR packet. Figure 2.A has been obtained with a load of 0.7 and figure 2.B 0.9. These traces correspond to a packet size of 1000 bytes (in this report we shall refer to packet size as the number of bytes of the 802.11 frames, i.e. including all headers). Note that with a load of 0.7 the response time is much lower and there are no losses.

The behavior observed in trace B makes evident that the wireless media is overloaded and the queue at the AP interface oscillates close to the maximum value. Since the background traffic is the same in both directions, AP and BG will become congested simultaneously. Thus, the service time of these stations will be two slots plus the additional time required by the 802.11 access protocol (backoff and RTS/CTS mechanisms). The response time observed in figure 2.B roughly corresponds to the time needed by MN to inject 200 packets (the queue length) into the wireless media. From the previous discussion we conclude it is 400 slots plus the additional time added by 802.11 access mechanism.

3.1 Response Time Analysis

Figure 3 summarizes the results obtained for packet sizes equal to 200, 500, 1000, and 2000 bytes. Figure 3.A gives the average response time in slots. The figure also shows the 95% confidence interval bounds for the simulation results.

Additionally, figure 3 shows the response time of an M/D/1 queue for comparison purposes. Note that in our scenario an ideal MAC protocol would behave as a single queue multiplexing the CBR stream with the background, i.e. an M+D/D/1 queue. Therefore, we can estimate the influence of the 802.11 MAC

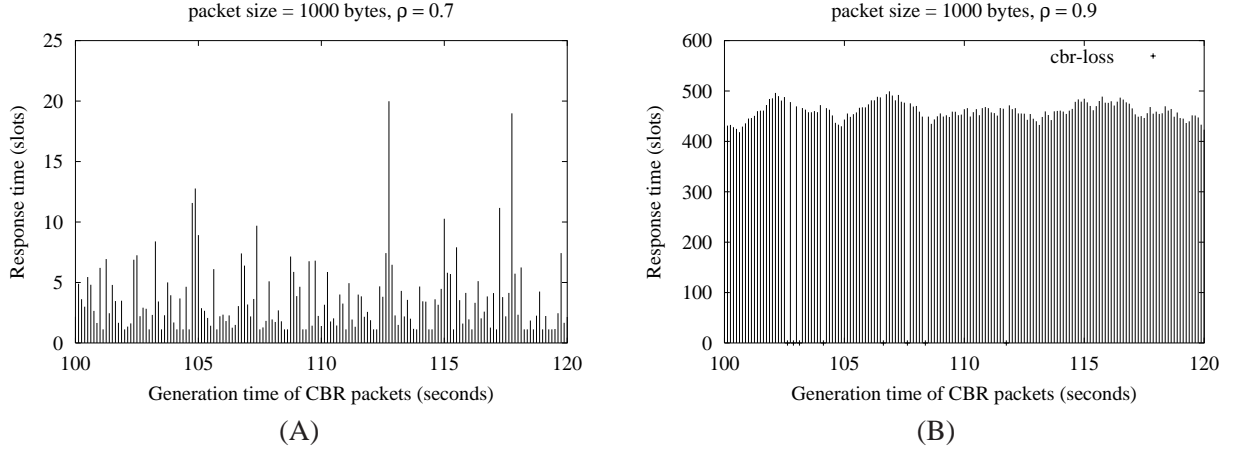


Figure 2: Trace showing the response time of CBR packets with a load (ρ) equal to 0.7 (A) and 0.9 (B).

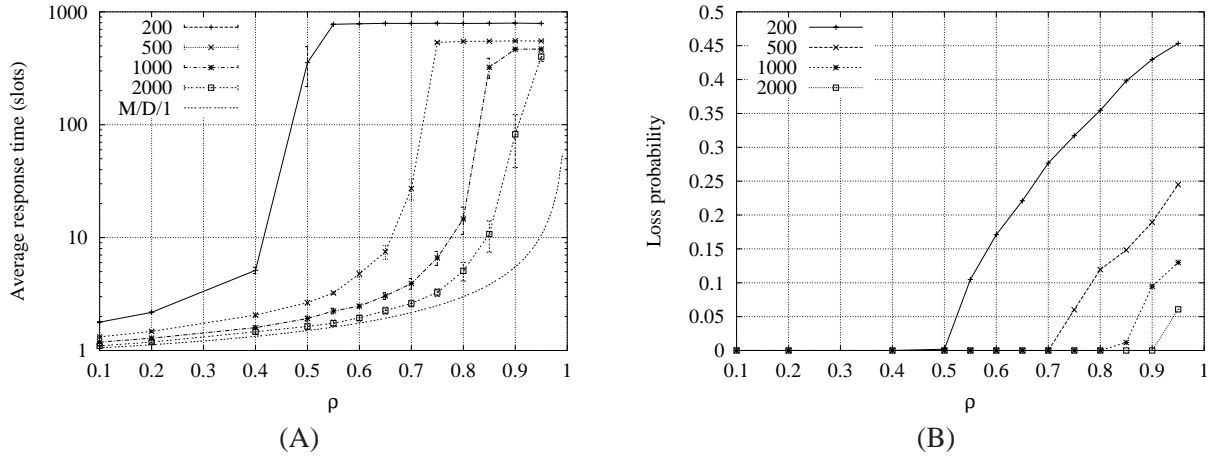


Figure 3: Average response time (A) and loss probability (B) of CBR packets for different packet sizes and loads.

protocol by confronting the simulation results with the “D” component of the output of an M+D/D/1 queue. Furthermore, since the CBR load is rather low (64 kbps/2 Mbps), we can approximate the response time of the M+D/D/1 queue by the M/D/1 queue ($1 + \rho/[2(1 - \rho)]$ slots).

Figure 3.B gives the loss probability of CBR packets measured in the simulations. Note that the measured CBR losses are zero until the wireless media becomes overloaded. At this point, loss probability grows approximately linearly with the load.

Figure 3 shows that the packet size has a huge influence on the response time. For instance, if we consider 10 slots as the maximum average response time, we obtain the results given in table 1. As shown in this table, the maximum load is reduced from 0.85 using packets of 2000 bytes, to 0.45 using packets of 200 bytes.

Packet size (bytes)	200	500	1000	2000	M/D/1
Maximum load	0.45	0.65	0.75	0.85	0.95

Table 1: Maximum load for an average response time ≤ 10 slots.

3.2 Playout Time Analysis

The average response time analyzed in previous section give us a measure of the overload state of the wireless media. However, for a typical real-time CBR stream, packets are only *usable* if their transmission delay is lower than a certain bound. We shall refer to this bound as the *playout*.

Figure 4 shows the probability of packets lost or dropped because they arrive later than the playout (measured in slots). For large playout values the curves remain equal to the loss probability (e.g. for a packet size of 500 bytes and $\rho = 0,75$ the loss probability is 0,07). It is interesting to note that for a playout of 200 ms (equivalent to 100 and 25 slots for packet sizes of 500 and 2000 bytes respectively), packets arriving later than the playout would be avoided for a maximum load of approximately 0.5 and 0.7 for 500 and 2000 bytes respectively. This result suggest that real-time applications may prefer using larger packets. In other words, the higher packetized time obtained with increasing the packet size may be compensated by the shorter response time introduced by the 802.11 access protocol using DCF.

As in the previous section, we can estimate the penalty introduced by the 802.11 access protocol by comparing the simulation results with an M/D/1 queue. Figure 5 shows this curve. Let $Q(x)$ be the complementary unfinished work distribution of an M/D/1 queue. Clearly, the probability of packets having a delay larger than the playout at the output of this queue would be given by $Q(x - 1)$. Figure 5 shows this distribution (computed by the method described in [10]). Note that in the M/D/1 queue there are no losses since we consider an unlimited queue size.

Confronting figures 4 and 5 we observe that 802.11 curves deviates considerably from the ideal multiplexing scheme given by the M/D/1 queue. Only for large packet sizes (2000 bytes) and low loads (lower that 0.7) the 802.11 access protocol reasonably approximates the M/D/1 queue.

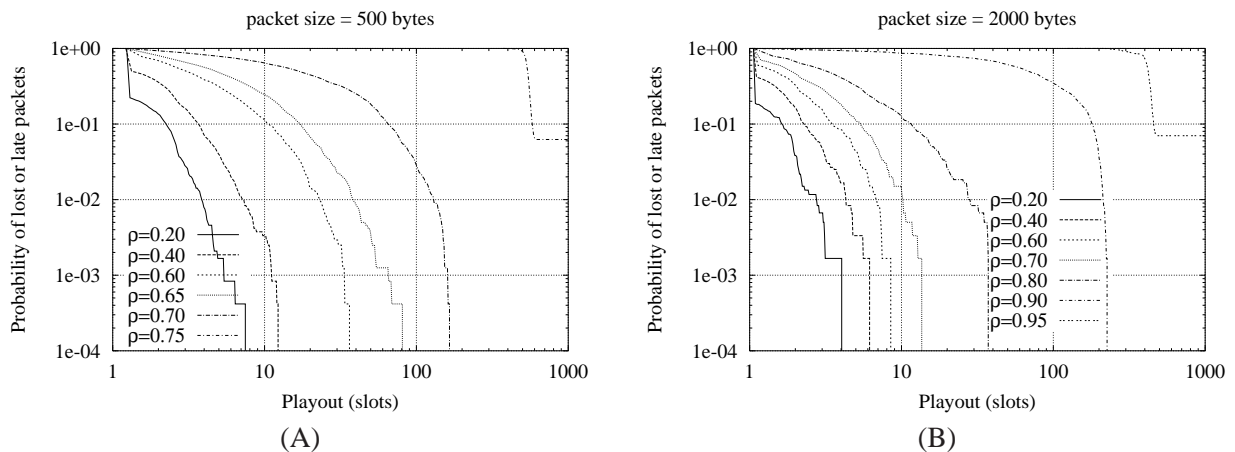


Figure 4: Playout for 500 (A) and 2000 (B) bytes packet size.

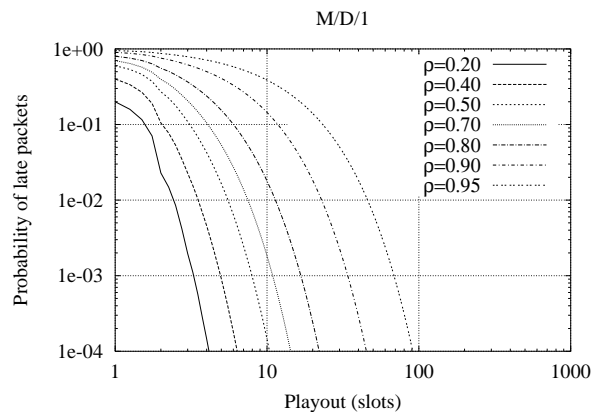


Figure 5: Playout for an M/D/1 queue.

3.3 Analysis Using Multiple Background Sources

In the previous sections we modeled the background by means of only one mobile node (BG) sending and receiving packets from the access point (AP). In this section we have increased to ten the number of mobiles nodes used to model the background (see figure 6). By confronting the results obtained in this section with previous ones we can estimate the robustness of the 802.11 when increasing the number of mobiles competing for the shared media.

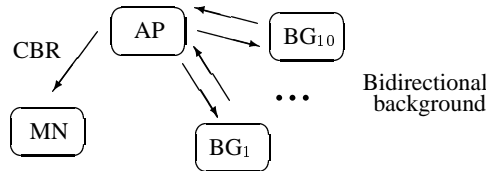


Figure 6: Network topology with ten background stations.

We have considered two scenarios:

- *Balanced* when the same amount of traffic is sent between AP and each BG. Since there are 10 BG stations, the AP sends 10 times more background traffic than a BG station.
- *Unbalanced* when every background packet is randomly sent by one of the AP or BG, $i = 1 \dots 10$ stations. Therefore, all of these stations send the same amount of background traffic.

Note that when increasing the background load in the balanced scenario, the AP will become congested much earlier than the BG stations. Instead, in the unbalanced scenario all transmitting stations will become congested nearly at the same time.

Figure 7 shows the delay and playout results for the balanced and unbalanced scenarios. Clearly, under overloaded conditions, the average response time is much higher in the unbalanced than in the balanced scenario. This is because, as explained before, in the balanced scenario only the AP is congested. However, for average response times lower than 10 slots, both scenarios present similar behavior (except for the case of 200 bytes packet size, where the unbalanced scenario becomes congested for shorter loads). Furthermore, it is also similar than the response time obtained for the scenario with only one background station (figure 3.A). The same conclusion can be obtained when confronting the playout curves with figure 4. Therefore, we can conclude that results obtained using only one background source may be a good approximation when the wireless media is not overloaded.

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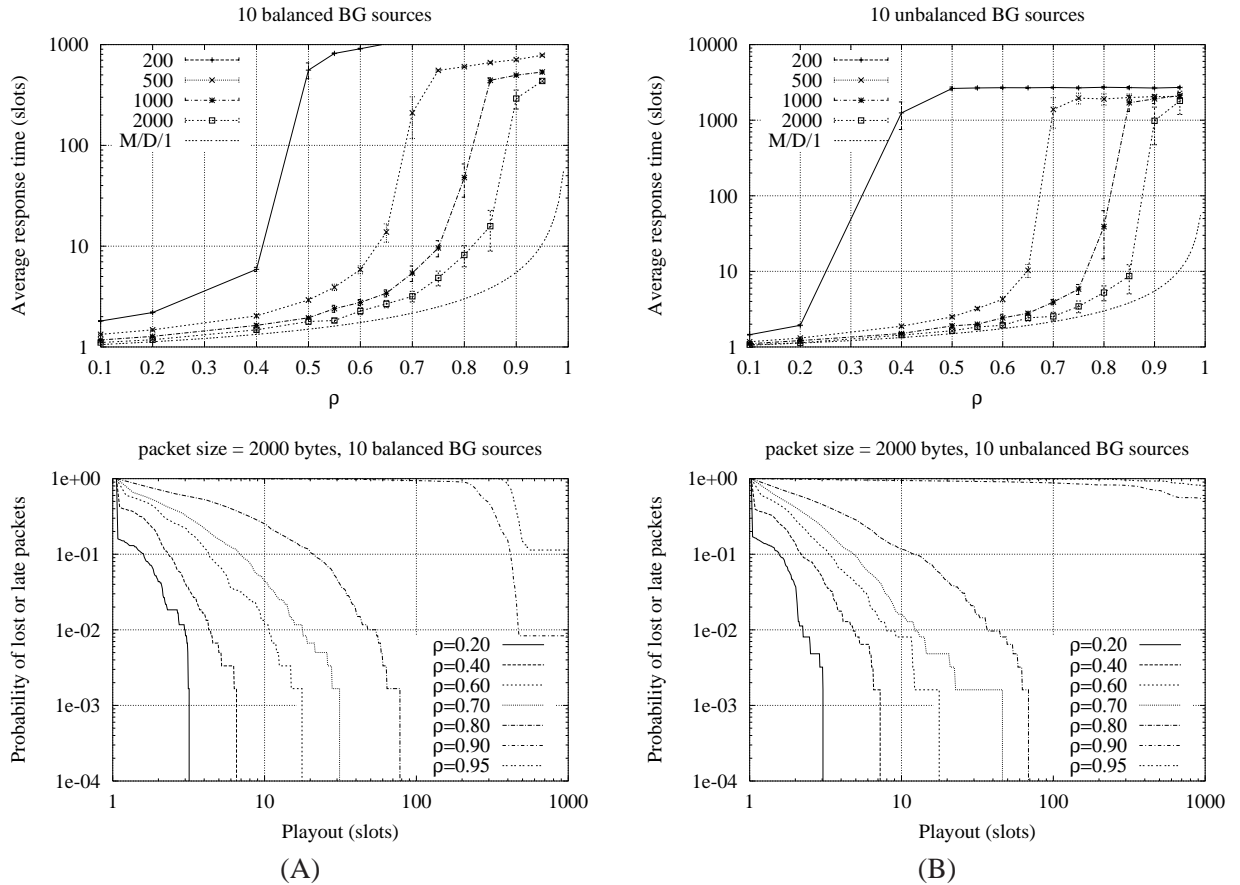


Figure 7: Average response time and Playout for the balanced (A) and unbalanced (B) scenarios.

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