Performance Comparison between the IEEE 802.3 CSMA/CD and the IEEE 802.11 DCF using Simulation

Chungmin Lee

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1 Introduction

Since DCF is developed to be used in more restricted environment than CSMA/CD, one can expect the performance of CSMA/CD is better than that of DCF. A simple, event-driven simulator for both CSMA/CD and DCF is written to verify that is correct. The simulator is first written in JavaScript and HTML, then some part of it is ported to C++ for faster simulation. Visit `http://lemon-factory.net/csma/` to run the JavaScript version of simulator in the browser.

2 Simulation Model

There are N stations contending for the medium. Each station has an associated traffic generator, which generates fixed-length packets according to a Poisson process of rate λ. Each station has also a buffer of infinite capacity so that the measured packet delay closely reflects the point of view of the user, or the upper layer protocol.

For faster simulation, a star topology is used for the CSMA/CD network. When a station transmits a signal, it reaches the other stations at the same time after the maximum propagation time passes. A bus topology was also implemented, but it is slow to simulate, and no significant differences in the results are found as long as the mean propagation time between stations are similar. The characteristic of a star topology (i.e. propagation times are the same for all pairs of stations) is also adopted for DCF due to the complexity of simulating the locations of mobile stations in a plane.

Numerical results will be obtained with varying N and λ, while the values of the other parameters is fixed. Those fixed parameter values are shown in Table 1. Note that the PLCP overhead is applied only to ACK frames, since ACK frames are so small that the overhead cannot be ignored.

3 Performance Metrics

Throughput, mean packet delay, and transmission collision probability are measured to analyze and compare the performance of CSMA/CD and DCF. The values are picked at least 5000 seconds (in simulation time) after the start of each simulation.

Throughput is the mean number of packets transmitted per second. Often it is normalized by the channel capacity; for the packet size of 1024 bytes and 10 Mbps transmission rate, the channel capacity is $1/(1024 \cdot 8/10000000) = 1220.70312$ packets per second.

Table 1: Parameter values for the simulation

	CSMA/CD	DCF
Packet size	1024 bytes	1024 bytes
Transmission rate	10 Mbps	10 Mbps
Maximum propagation time	20 µs	2 µs
CW_{min}	1	15
CW_{max}	1023	1023
Retransmission limit	16	11
Slot time	51.2 µs	20 µs
SIFS	-	10 µs
DIFS	-	50 µs
Interframe gap	96 bits	-
PLCP overhead	-	20 µs (for ACK only)
ACK frame size	-	14 bytes
ACK timeout	-	41.2 µs (SIFS + AckTxTime)

Mean packet delay is the time from a generation time of a packet to the time that the transmission of the packet is completed. For DCF, a transmission is completed if and only if an ACK frame is successfully received.

Transmission collision probability is the probability that a station trys to transmit a packet through the medium and the transmission fails due to a collision.

4 Performance Comparison

4.1 Variable Load

Figures 1 to 4 show the obtained values versus offered load for $N = 10, 20, 40, 80$. Offered load is the sum of the packet arrival rate per station, or $\Sigma\lambda = N \cdot \lambda$. Normalized offered load is offered load normalized by the channel capacity.

Regardless of MAC or the value of N, throughput increases linearly as offered load increases when the load is low. Then at some point the increasing rate is lowered and eventually the throughput remains unchanged. In some cases this "saturated" throughput is lower than the maximum throughput.

Figure 2 shows the maximum and the saturated throughput from Figure 1. The maximum achievable throughput is one-third higher for CSMA/CD than that for DCF, indicating the overhead in DCF is quite large. The figure also shows that DCF is more adversely affected by increasing number of stations. These can be predicted from the fact that a collision is expensive for DCF. Collisions occur frequently under heavy load and when there are large number of stations.

There are only negligible differences in mean packet delay when the load is low although it is higher for DCF than for CSMA/CD. The delay for DCF remains low and does not change much as the load varies. Then it suddenly approaches infinity when the throughput is saturated. In the case of CSMA/CD, the delay can be as high as 1000 ms before the throughput becomes saturated. It increases exponentially when the normalized load is between 0.8 and 1.

The transmission collision probability is remarkably low for DCF. It remains below 0.1 before saturated whereas it increases almost linearly for CSMA/CD when the normalized

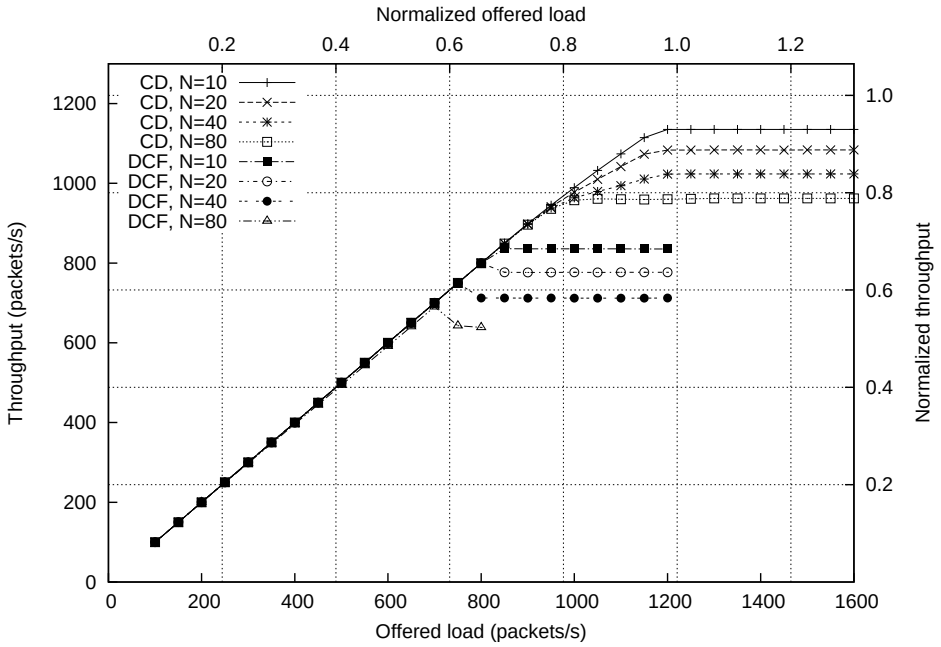

Figure 1: Throughput versus offered load

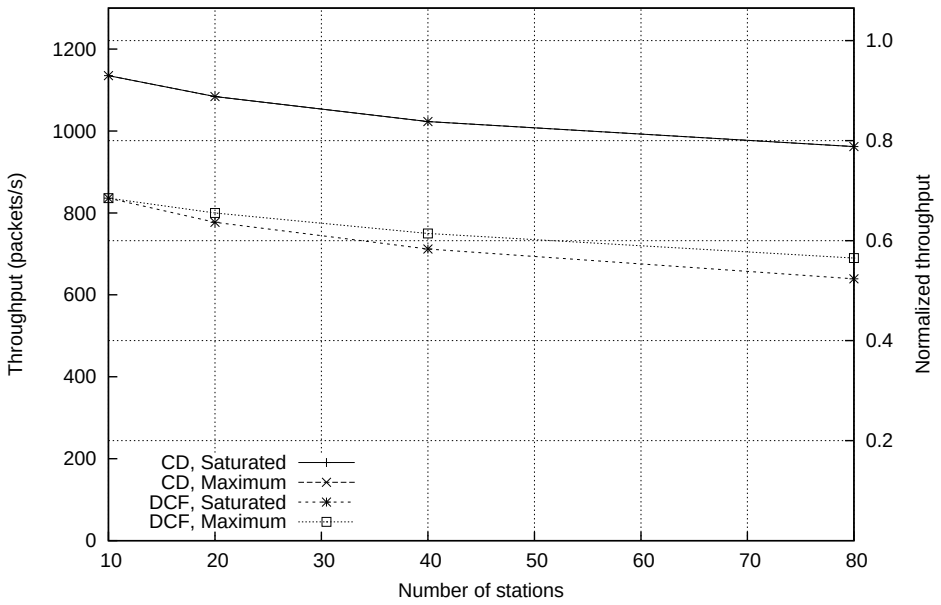

Figure 2: Maximum throughput and saturated throughput versus number of stations

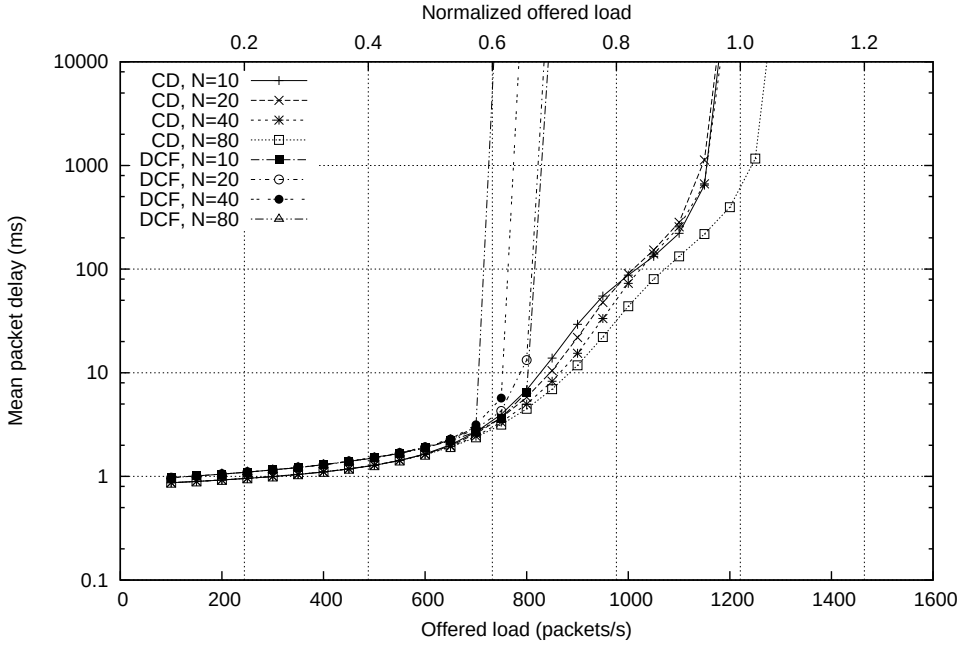

Figure 3: Mean packet delay versus offered load

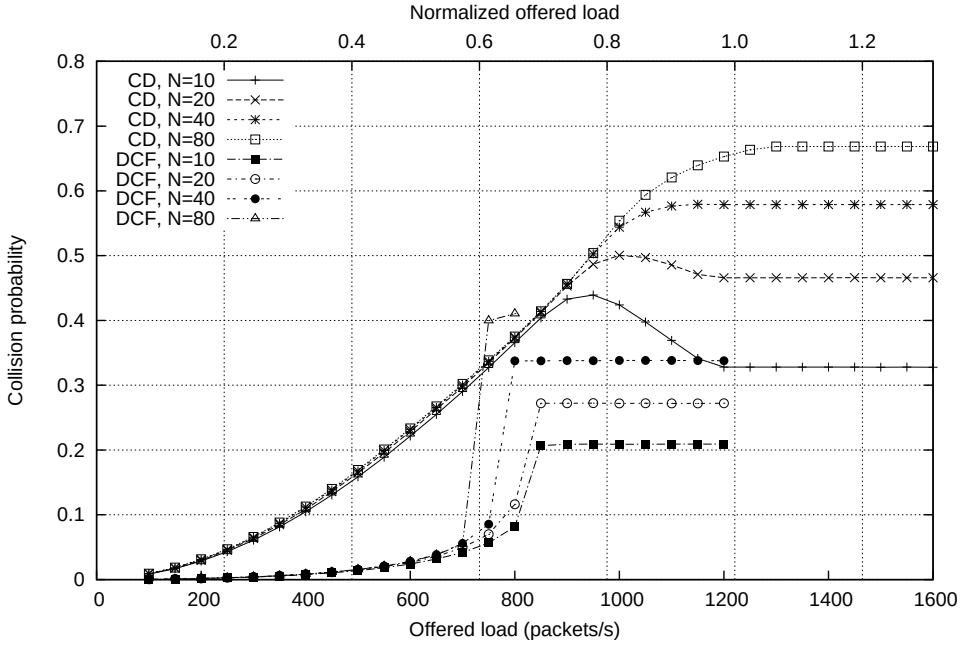

Figure 4: Transmission collision probability versus offered load

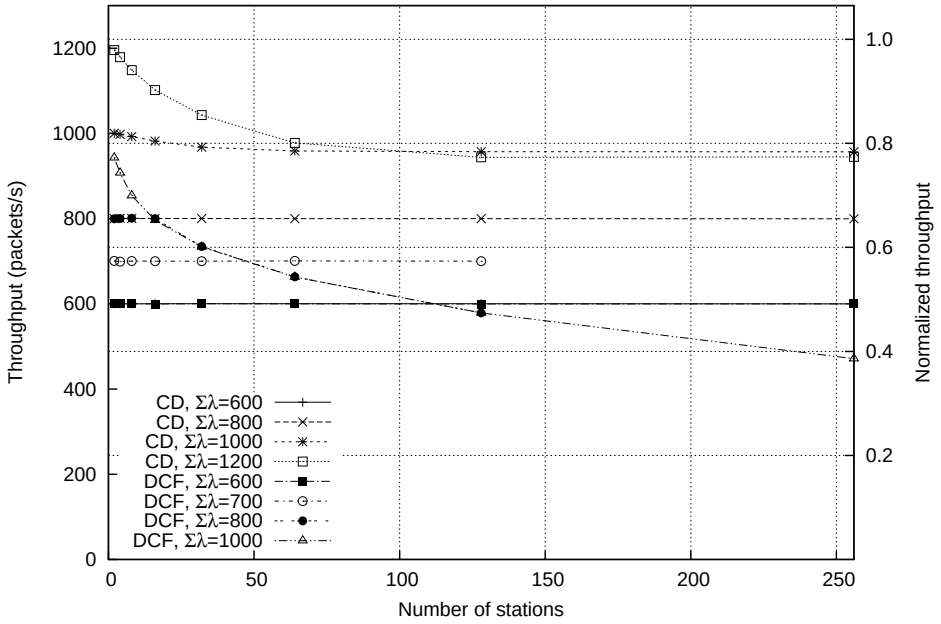

Figure 5: Throughput versus number of stations

load is lower than 0.8. When $N \leq 20$, the collision probability decreases for CSMA/CD where the normalized load goes from 0.7 to 1. It might be due to the capture effect of CSMA/CD. The binary exponential backoff mechanism used in CSMA/CD is not fair in that it favors the last transmitted station. This effect may reduce collisions, improve throughput, at the expense of the increased mean packet delay.

4.2 Variable Stations

Figure 5 to 7 show the measured values versus number of stations for various values of offered load $\Sigma\lambda$.

Figure 5 confirms that the throughput of DCF is more adversely affected by the increasing number of stations than that of CSMA/CD. Note that although for CSMA/CD and $\Sigma\lambda = 1000$ the throughput seems saturated, it is actually under the effect of increased packet drops due to the retransmission limit.

Figure 6 and 7 shows further that the performance of DCF worsens drastically in every aspect as the number of stations increases. Interestingly, the performance of DCF show no difference between $\Sigma\lambda = 800$ and $\Sigma\lambda = 1000$ when $n \geq 32$.

5 Conclusion

Both protocols exhibit good characteristics when the normalized load is less than 0.5. The transmission collision probability is markedly low for DCF as the name Collision Avoidance suggests. But both protocols do have overhead and the maximum achievable throughput is lower than ideal. For DCF it is especially low and worsens significantly with growing number of stations.

As expected, DCF is proved to be inferior to CSMA/CD. That is the conclusion. But there might be small changes to the protocol that improve the performance. Although it is not included in this paper due to the lack of time, it is possible to reduce collisions if

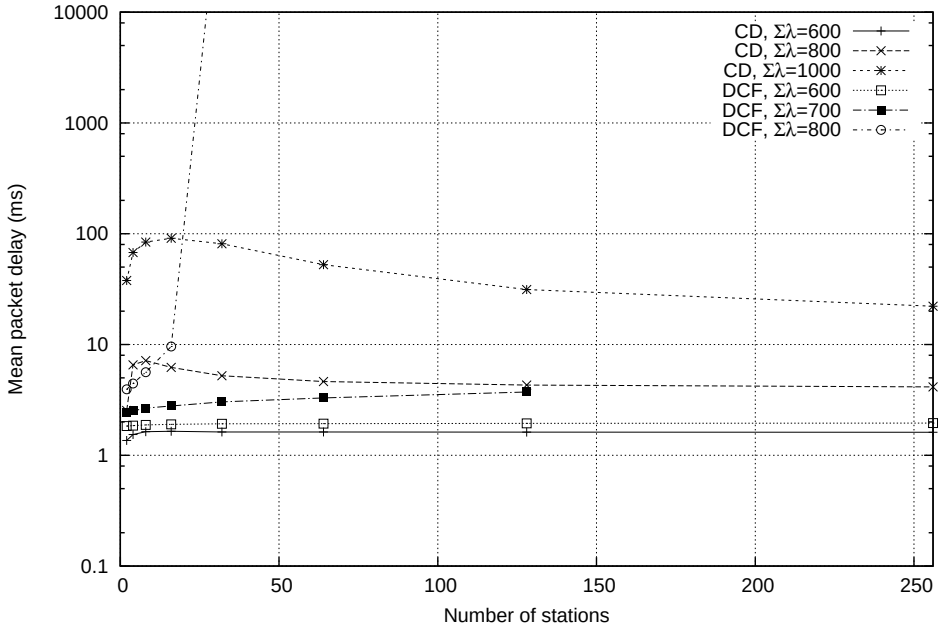

Figure 6: Mean packet delay versus number of stations

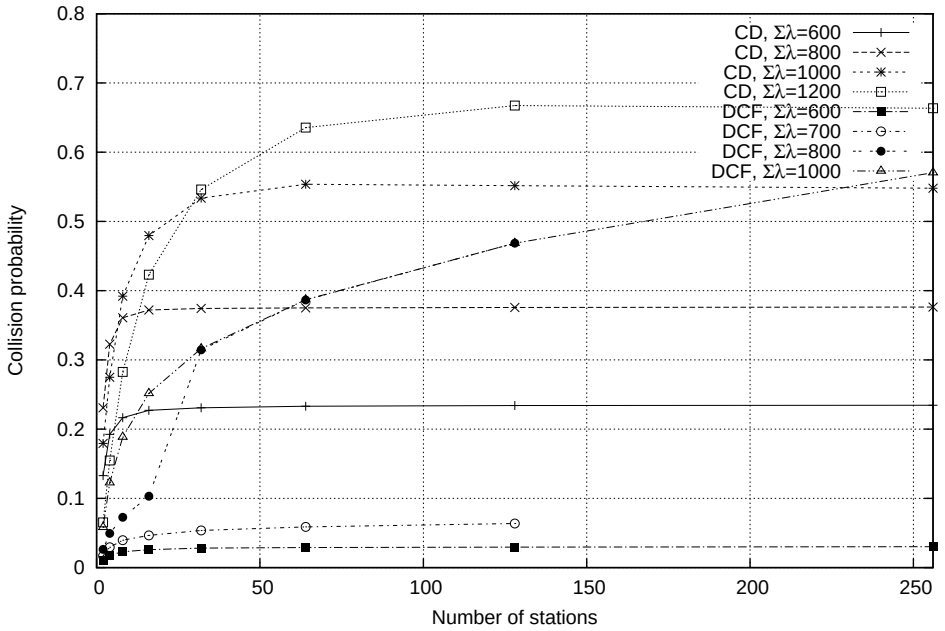

Figure 7: Transmission collision probability versus number of stations

the backoff counter can be a floating number rather than an integer. It was found by a coding mistake.