IEEE P802.11
Wireless LANs

Evaluation of 802.11 Protocol Efficiency

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Abstract

As the 802.11 evolved and different Phisical layers (PHY's) with higher rate support where adopted, the MAC layer stayed static and received this PHY's as legacy. This document analyzes the efficiency of the protocol for the different PHY's defined in the 802.11 standard, and focuses on the high efficiency degradation existent between the original MAC-PHY scheme at 2Mbps and the new PHY's defined lately. The analysis has been performed on transaction basis. It means that an isolated data frame transaction has been considered. Thus such MAC elements as backoff have not been taken in account. Protocol efficiency was calculated for different packet sizes as well as different transaction scenarios. Finally, some general recommendations on how to increase protocol efficiency are discussed.

Protocol efficiency in data transfer is calculated as follows:

$$Eff = \frac{ND}{TrD * NDR}$$

Where:

- ND = Amount of Network Data. Three values where taken in consideration:
  - 60 bytes (shortest Ethernet packet)
  - 400 bytes (average)
  - 1500 bytes (maximum)
- TrD = Transaction Duration (μsec). Three transactions where taken in consideration:
  - DATA-ACK
  - RTS-CTS-DATA-ACK
  - CF Poll{+DATA} – Cf-Ack{+DATA}
- NDR = Nominal Data Rate. Four rates where taken in consideration:
  - 2 Mbps
  - 11 Mbps
  - 24 Mbps
  - 54 Mbps.

Protocol events like backoff, collisions, etc. have NOT been taken in account. So the actual performance will be less than the calculated.

1. DCF Mode

Table 1 summarizes the relevant timing information for the calculation of protocol efficiency:

	2Mbps	11 Mbps	24 Mbps	54 Mbps
SIFS	28	10	16	16
DIFS	128	50	34	34
Preamble	128	96	16	16
ACK[1], CTS[1]	240	107	28	24
RTS[1]	288	111	28	24
Data Small[2] (60 bytes)	480	160	52	36
Data Medium[2] (400 bytes)	1840	408	168	88
Data Large[2] (1500 bytes)	6240	1208	532	248

Table 1: Duration information (msec)

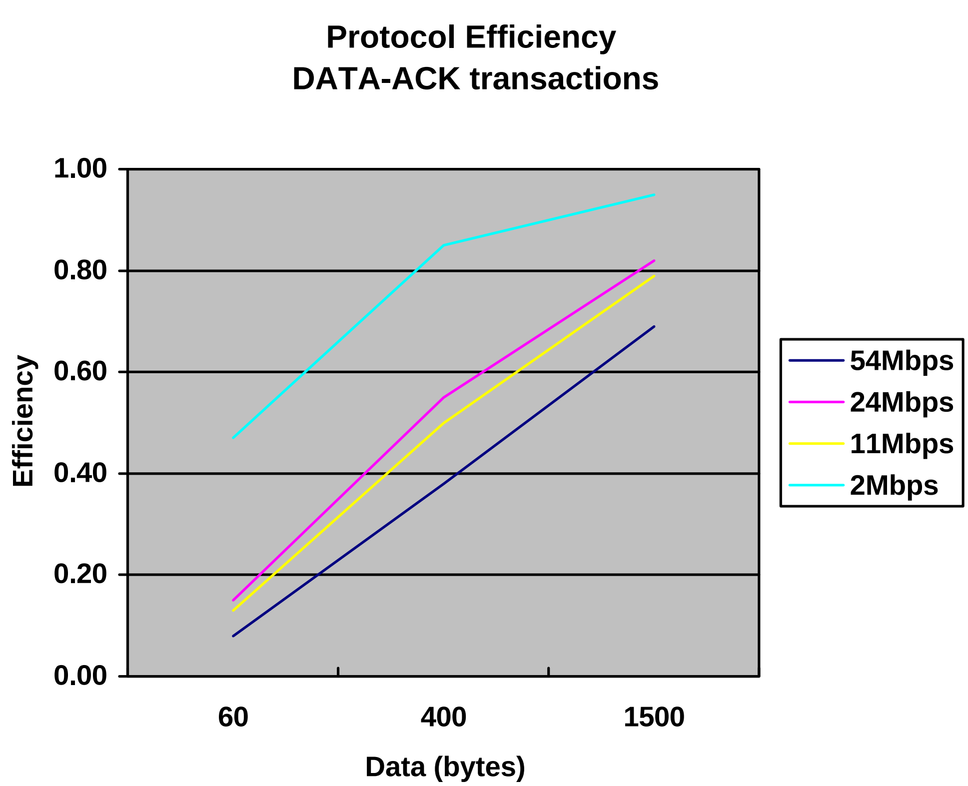
[1] Including Preamble and PLCP Header
[2] Including Preamble, PLCP Header and MAC header

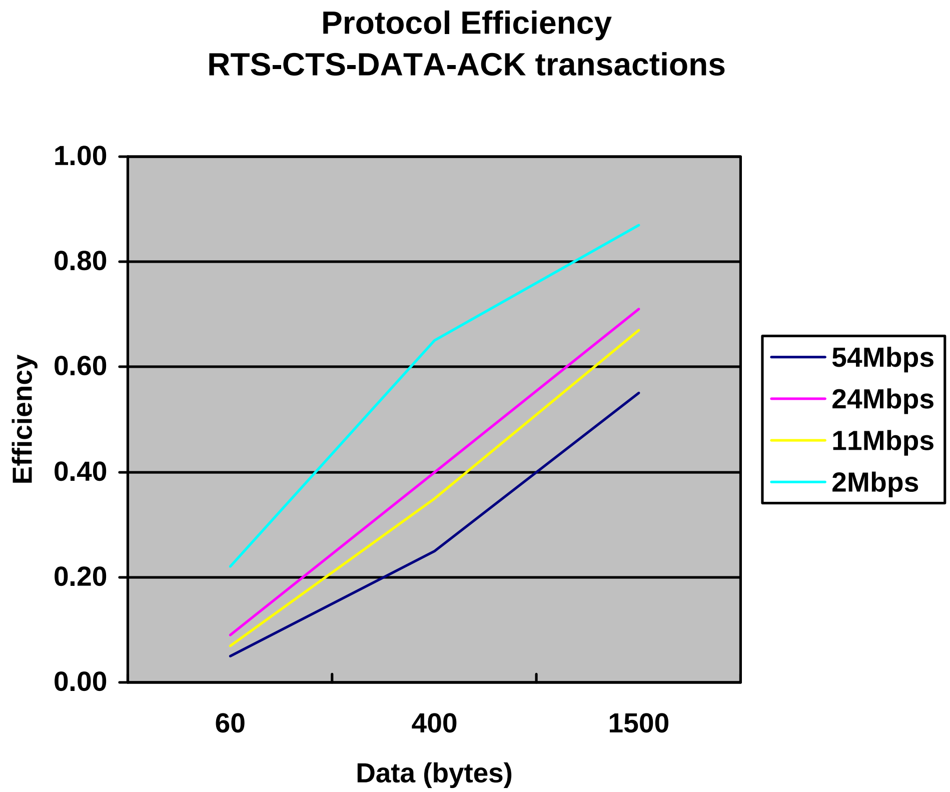
Table two shows the calculation of the protocol efficiency for each scenario:

D (μsec) = Raw data to be transmitted (bits) / Rate(Mbps)
TrD(μsec) = DIFS + Data + SIFS + ACK (Data-ACK)
DIFS + RTS + SIFS + CTS + SIFS + Data + SIFS + ACK (RTS-CTS-Data-ACK)

		Data – ACK			RTS-CTS-Data-ACK		
		Shortest	Average	Largest	Shortest	Average	Largest
2Mbps	D (μsec)	240	1600	6000	240	1600	6000
	TrD (μsec)	508	1868	6268	1092	2452	6852
	Eff	**0.47**	**0.85**	**0.95**	**0.22**	**0.65**	**0.87**
11Mbps	D (μsec)	44	291	1091	44	291	1091
	TrD (μsec)	327	575	1375	565	813	1613
	Eff	**0.13**	**0.50**	**0.79**	**0.07**	**0.35**	**0.67**
24Mbps	D (μsec)	20	134	500	20	134	500
	TrD (μsec)	130	244	610	218	332	698
	Eff	**0.15**	**0.55**	**0.82**	**0.09**	**0.40**	**0.71**
54Mbps	D (μsec)	9	60	223	9	60	223
	TrD (μsec)	110	162	322	190	242	402
	Eff	**0.08**	**0.38**	**0.69**	**0.05**	**0.25**	**0.55**

Table 2: Protocol Efficiency





- In small packets, performance drop between high rate PHY's and 2Mbps is 0.32-0.39 for DATA-ACK transactions and 0.13-0.17 for RTS-CTS-DATA-ACK transactions. Efficiency reaches a low value of 0.08 at 54 Mbps.
- In medium packets, the average drop is 0.30, although at 54Mbps the drop increases to more than 0.40. Efficiency reaches 0.38 at 54 Mbps
- Large packets are less affected in DATA-ACK transactions with a drop between 0.13-0.26, while for RTS-CTS-DATA-ACK transactions the drop is between 0.16-0.32. Efficiency reaches 0.69 at 54 Mbps.

2. PCF Mode

In PCF mode the protocol performance depends strongly on the protocol flow. The flow is defined by the demand and polling policy so there are no straightforward answers, flow simulation required.

The following are the results of simplified PCF mode considerations.

The model considered was to transfer **average** (400 bytes length) packets using some mix of the following transactions required:

1st. Data(dir)+CF-Poll - Data(dir)+CF-Ack
2nd. CF-Poll(No data) – Data (with CF-Ack in the next polling)

3rd. Data(dir)+CF-Poll – CF-Ack(No data)

Note that the transactions A and B require the same time.
In addition, some amount of unsuccessful polling attempts is present:

4th. CF-Poll(No data) – PIFS

	54Mbps
PIFS	25
CF-Poll[3]	28
CF-Ack[3]	28

Table 3: PCF Duration information (msec)

% of A type Transactions	% of B+C type Transactions	Number of D type events per transaction	Average Transaction time, μsec	Efficiency = Amount of Data / Average Time / Rate
30	70	0	135	0.44
		1	213	0.28
		2	291	0.20
50	50	0	126	0.47
		1	204	0.29
		2	282	0.21
100	0	0	104	0.57
		1	182	0.33
		2	260	0.23

Table 4: PCF Protocol efficiency for 54 Mbps

These results show that PCF transactions of the type A provide efficiency less than 0.33 in the case of at least one D-type event per transaction. Compare this with the corresponding results of 802.11 original 2 Mbps standard:

% of A type Transactions	% of B+C type Transactions	Number of D type events per transaction	Average Transaction time, μsec	Efficiency = Amount of Data / Average Time / Rate
100	0	0	2208	0.72
		1	2698	0.59
		2	3188	0.50

Table 5: PCF Protocol efficiency for 2 Mbps

[3] Including Preamble and PLCP Header

3. Conclusion

There is quantitative efficiency degradation in all scenarios analyzed. This degradation affects also DCF and PCF modes and alternative ways to improve this efficiency at MAC layer should be analyzed.

The degradation appears obviously as a result of greater (overhead time / data transfer time) ratio and growing coding granularity (only integer number of OFDM symbols can be transmitted).

4. Recommendations

The following improvements might be proposed to increase performance. They all are based on idea of aggregation of data and control information

1. The downlink data and control information can be aggregated into greater frames. At the receiving station such a frame will be disassembled to extract the part addressed to this station. The improvement might be considerable for small packets.

2. The uplink feedback information can also be aggregated: a single ACK can acknowledge a group of original LAN frames. The increase for a medium length frame can be around 5-10 %.

3. The uplink transmissions can be scheduled in advance by the Access Point. This requires developing certain reservation procedure including delivery of reservation requests. This can be seen as an improvement to PCF.

To employ all the above ideas a superframe approach might be applied with as large DL and UL frames as possible. The reservation requests might be piggybacked on the data frames or sent within contention window.

Implementation of 1 and 2 is possible with minor changes in the MAC.

5. References

- IEEE P802.11/D10
- IEEE P802.11a/D7
- IEEE P802.11b/D7