IEEE P802.11
Wireless Access Method and Physical Layer Specifications

Title: The importance of the tx-rx switching time on the MAC protocol performance

Author: Pablo Brenner
LANNAIR Ltd.
Atidim Technological Park
Devorah Haneviah St. - Neve Sharet
Tel Aviv 61131 - ISRAEL
Voice: +972-3-6458375
FAX: +972-3-5447146
EMail: pablo@lannet.com

Abstract:

This paper describes the importance of the transmit to receive switching time, and how this affects the different MAC protocol's performance, even when we expect significant improvements on the next generation of radio devices. A following document will describe techniques that could be used for designing MAC Protocols independent of this parameter.

Related Documents:

IEEE P802.11-92/39 Medium Access Control Protocol for Wireless LANs
IEEE P802.11-93/33 802.11 MAC Requirements and Comparison Criteria.
IEEE P802.11-93/40 The WHAT MAC Protocol.
IEEE P802.11-93/83 Draft Proposal for a FH and DS SS PHY Standard.

Introduction

The current proposals for Frequency Hopping PHY, define a tx-rx switching time of about 100 microseconds[SIL93]. The intention of this paper is to describe how this parameter affects MAC performance on each of the existing MAC proposals, and to explain why it should be taken in consideration, even when we expect next generations of radio devices to reduce this limitation in the "near" future.
A subsequent proposal will show techniques that could be used during the MAC protocol design to eliminate the overhead injected by this parameter.

Tx-Rx switching time

This parameter indicates the amount of time that is required in a radio device to switch from full transmission to full reception, the main contributors to this switching period are usually the tx-rx leakage and the receive path memory.

While in Direct Sequence Spread Spectrum devices this parameter is quite insignificant (about 10 µsec.), in Frequency Hopping devices this time is usually large (about 100 µsec.)

Because of the fact that all the existing MAC proposals use a set of transactions for each frame to be transmitted (all the proposals use at least one ack frame for each data frame, and some of them in addition use an RTS/CTS transaction), the amount of time "wasted" because of this PHY limitation oscillates between 200 and 400 µsec. for each data frame independently of the frame size.

To get some proportion of the magnitude of this "wasted" time, it should be noted that a 64 byte long frame at a 1 MBit/s rate is transmitted in 512 µsec, so for an RTS/CTS type of protocol, the overhead caused by the tx-rx switching time is of 43.8% (without considering the overhead of the RTS, CTS, and ACK frames themselves).

In fact this overhead is considerably reduced if we use long frames, but because of the big BER of the medium, most protocol proposals talk about fragmentation, which for the purpose of this paper is like assuming short (or medium) sized frames.

When this issued was brought up on the May 93 meeting at Wilmington, the group's answer was that even when this could prove to be a problem on this generation of radio devices, the radio technology will soon reduce significantly this switching time on the next generation of devices. I completely agree with this assumption, but my understanding is that this just makes things worse, this is shown in the following example.

Example:
Lets assume that the MAC protocol doesn't define any limitation on the minimum time a station should wait before sending an acknowledge, and the acknowledge is transmitted as soon as possible, and assume we have two stations A and B with radio transceivers of the first generation (tx-rx-switch-time = 100 µs.).

Assume Station A transmits to Station B, and immediately switches to receive mode, Station B receives the packet after n µsec (but we cannot impose any lower limit to the propagation time because we are not limiting how near could these 2 stations be), processes the frame and acknowledges. So the time passed until Station B receives the acknowledge is:
t_ack = 2 * prop_time + max (frame_processing_time, rx_tx_time)
which in order to work must be lower than 100 µsec.

This will probably work on the first generation, where the frame_processing_time may be large, or the rx_tx_time could be large (should be less than tx-rx, but on the same order of magnitude).

Now lets assume that Station B is upgraded to a second generation of WLAN adapters (the protocol wasn't changed of course, we are not going to change the protocol any time the technology is upgraded), but Station A is kept as before (the station is not critical to the customer so he didn't want to waste money upgrading it).

Station A transmits the packet and switches to receive, Station B is so much faster (the rx_tx_time, and the frame processing time were reduced significantly), that acknowledges in just 10 µsec, much before Station A is ready to accept the acknowledge, which will cause Station A to retransmit, and so on.

The bottom line is:

The MAC protocol must define what's the minimum (and probably maximum) time that a station MUST wait until it acknowledges, which must always be greater (or equal) to the tx-rx switching time

Analysis of tx-rx switching time overhead on existing proposals

This analysis assumes a 100 µsec. switching time, and a bit rate of 1 MBit/sec.
Note: The frame sizes and their headers may not be accurate and may change, but I still think they are representative.

Xircom's WHAT protocol [BIB93]

For each data packet we have the following transactions:

RTS packet (16 * 8 bits = 128 µsec.)
Wait tx-rx-sw-time (100 µsec.)
CTS packet (8 * 8 bits = 64 µsec.)
Wait tx-rx-sw-time (100 µsec.)
Data packet ((16 + n)*8 bits = 128 + n*8 µsec.)
Wait tx-rx-sw-time (100 µsec.)
Ack (7 * 8 bits = 56 µsec.)
Wait tx-rx-sw-time (100 µsec.)

So the total transmission time for an n-bytes packet is:
t(n) = 776 + n*8 µsec.

The following table shows the total protocol overhead and the tx-rx-sw-time overhead for different frame sizes:

n [bytes]	t(n) [µsec.]	total overhead [%]	tx-rx overhead [%]
64	1288	60.24	31.05
256	2824	27.48	14.16
1000	8776	8.84	4.56

IBM's SuperFrame Based Protocol [NAT92]

In IBM's proposal the overhead depends also on the SuperFrame size, in this analysis we will assume a SuperFrame size of 20 milliseconds (a bigger SF size would get less tx-rx overhead, but higher delay, and a smaller SF would give better delay but worse overhead).

In this proposal the tx-rx overhead appears in the following periods:
Two transitions after each data frame transmission (because of the immediate ACK)
One transition after B Header
One transition after CH Header
One transition before AH Header

For this protocol analysis we will include in t(n) the two transitions, plus the relative part of the SuperFrame transitions according to the frame size.

$t(n) = n * 8 + 200\ \mu sec. + (n * 8\ * 300)/20{,}000$

n [bytes]	t(n) [µsec.]	tx-rx overhead [%]
64	720	28.89
256	2278	10.1
1000	8320	3.85

Conclusion

I believe a new issue should be opened:
How does the tx-rx switching time affect MAC protocol performance?

and add it to the list of criteria for MAC evaluation.

References

[SIL93] N. Silberman, ed., Draft Proposal for a FH and DS SS PHY Standard. IEEE P80211-93/83

[BIB93] K. Biba, P. Belanger, The WHAT MAC Protocol, IEEE P802.11-93/40

[NAT92] K.S. Natarajan, Medium Access Control Protocol for Wireless LANs, IEEE P802.11-92/39

[DIE93] W. Diepstraten, MAC Requirements and Comparison Criteria, IEEE P802.11-93/33