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Wireless Access Method and Physical Specification

Title: **The importance of short Rx-Tx Turnaround time.**

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Abstract: This paper discusses the importance for a fast Rx to Tx (and reverse) turnaround time. This paper stresses the importance of this parameter, because it can present severe limitations on all future standards that can operate in the same band. This parameter can have large effects on the effectiveness of the MAC protocol.

This document does also contain a recommendation to add parameters to the PHY template that are applicable to the MAC. It further includes recommended changes for the currently specified parameters.

Proposal: A new issue should be opened to specify the parameters the MAC wants from the PHY.

Introduction:

The importance of the switching time and the anticipated affects on the different MAC protocols was first addressed by Pablo Brenner in [1]. The current PHY specifications list a 10 usec switching time for Direct sequence, and a significant larger time of 100 usec for the Frequency Hopping devices. In addition in Proxim is even suggesting to double this time in their 1.6 Mbps Frequency Hopping proposal [2].
This will have severe implications as already pointed out in [1], and it does seriously limit migration towards higher speed standards that are expected in the same band.

It is considered very important that sufficient focus is given to performance efficiency when utilizing the scarce spectral resources we have to work with, and to give sufficient consideration to the needs of todays applications that are designed on todays higher speed wired standards.
It is therefore important to stress this parameter as much as possible even when this would limit the transceiver architectures that can be applied.

The effect of the switching time on MAC performance:

The effect on performance is caused by several switching aspects.

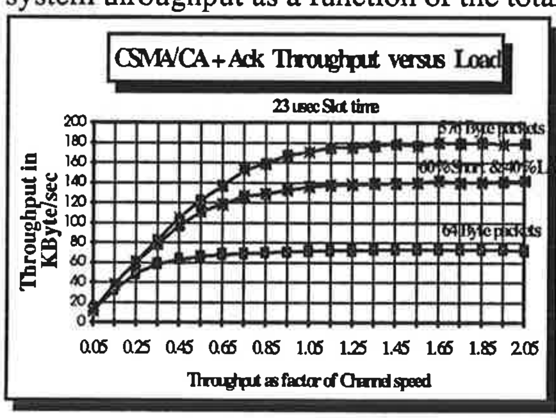
- There is the effect of the increased overhead that occurs when a quick mutual exchange between transmitter and receiver is needed. Examples are the Ack packets that are part of all existing MAC proposals, or the RTS,CTS,DATA,Ack exchange that is being used in the "WHAT"protocol. The delay of at least the worst case time of either Tx-Rx or Rx-Tx switching needs to be maintained for succesfull completion of the frame transactions. The effect of this for the different protocols is shown in [1].

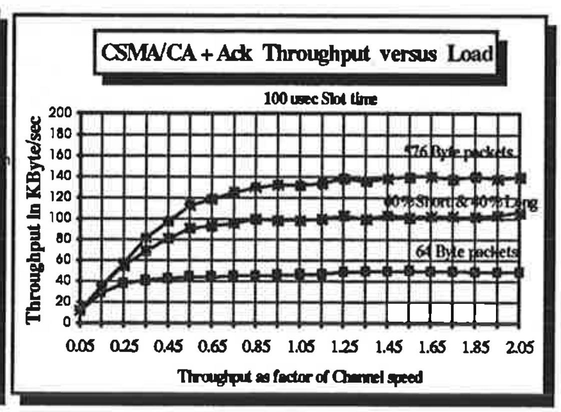
- In a CSMA based protocol, an important parameter will be the total time it takes from ***detecting an idle medium, and subsequently turn on of the transmitter***. This time represents the resolution of the CSMA mechanism, and determines the collision probability. When the switching time is long relative to the CS detection time, then the probability that more stations are still sensing an idle medium while a station is already switching to transmit mode is increased, causing the increased collision probability.

- In a CSMA/CA system, a collision avoidance technique is being used that intends to reduce the collision probability there where its probability is the highest. This is immediately after the medium becomes available again after a transmission. The CSMA/CA transmitter will be forced into random backoff delay before the medium is sensed again for availability. To resolve contention between multiple stations that try to access the medium at approaximately the same time requires a backoff window of several slots.

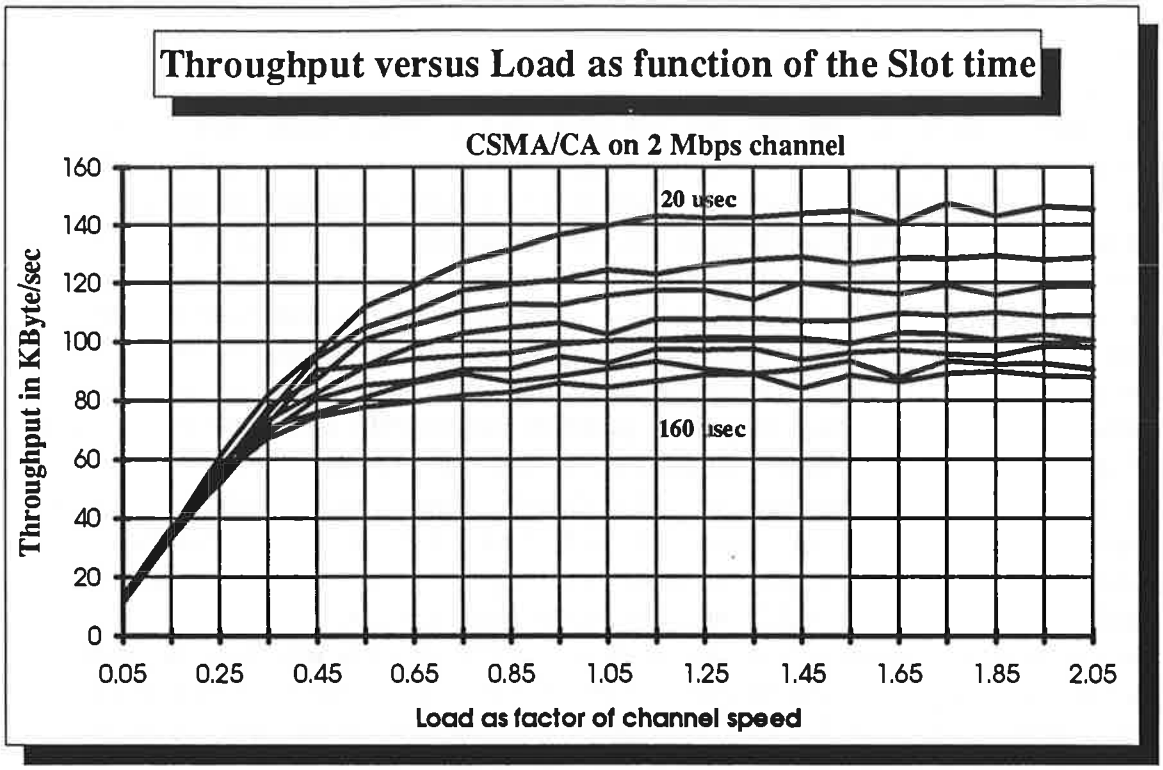
The length of the slot should be equal to the total of the ***"CS detect time"+"Rx-Tx switching and Tx turn-on time"+"medium propagation delay time"***. Increase of the switching time will cause a severe effect on the total throughput under high load condition, and will decrease the response time.

The following diagram shows the total effect of the above discussed aspects on the total system throughput as a function of the total slot time.





It is shown that the protocol efficiency difference is about 28% for the examples provided, using the mixed packet length results. This is the case for the 2 Mbps bitrate that is assumed in the above simulations.



When in the future higher bitrates would become available due to improvements in both Radio technology and level of integration, then the effects will become more severe, because the delays in terms of bits will relatively increase.
As discussed by Pablo Brenner in [1], these parameters can not be improved when technology improves, because compatibility needs to be maintained with the first generation of standard products.

It is the expectation that higher speed (defacto) standards will develop in the same band, which will result in products that will provide backwards compatibility to the lower speed standards that are currently being developed. However for the same reasons as explained in [1], the MAC would not be able to utilize the full potential of the higher speed and advances in technology, because the worst specified Rx-Tx switching times need to be maintained, in order to assure coexistance and interoperability.

What are the trade-offs

The large switching times that have been specified in the current Frequency Hopping PHY specification are due to the limitation that is apparent in a particular transceiver architecture. This is applicable to the combination of a Homodyne transmitter and a

Hetrodyne receiver, where a single VCO is shared between the transmitter and receiver. In this particular case, the VCO needs to switch frequencies every time it switches from TX-to-Rx or Rx-to-Tx. The switching time that can be achieved is limitted by the settling time required to achieve a certain LO jitter tolerance. The hetrodyne receiver is likely required because of the channel selectivity requirements in both standards, which is hard to meet otherwise.
These solutions are popular because they are relatively low cost, although extra effort is required to isolate the VCO from the Power stage and antenna, to prevent pulling. This effect becomes even more severe when solutions with integrated antenna are being used, which will make this type of architecture less and less attractive because of the severe isolation that needs to be designed in, that will cause the cost and complexity to increase.

A much more promising solution is a more symetrical approach that eliminates the need to switch VCO frequencies when switching between Tx and Rx and visa versa. This can be obtained by using both a Hetrodyne transmitter and receiver using the same IF frequency. This will also reduce the pulling problem considerably, so that the extra cost of the IF section pays off in reduced isolation requirements in the transmitter.
When no VCO frequency switching is needed, then this almost eliminates the total Rx-to-Tx turnaround time, because the transmitter can be turned on immediately after the medium is sensed idle. Only a small Tx power ramp-up time needs to be considered. This may still cause some pulling or LO jitter effects, that need to settle.

Perhaps a longer preamble is needed to allow this jitter to settle within the required limits that allow proper receiver operation. This is far less of an issue, because it would not increase the CSMA/CA slot time, because the transmitter is turned on immediately, which allows remote receivers to already detect that the medium is busy.
So an increase of the preamble does not affect the collision window.

What parameters need to be specified in the PHY:

This section reviews the PHY parameters that are important for the MAC operation. It does discuss the definition of the parameter as it is applicable for the MAC, and it flags where the current PHY template definitions need to be changed.
The relevant parameters to a MAC are listed as follows:

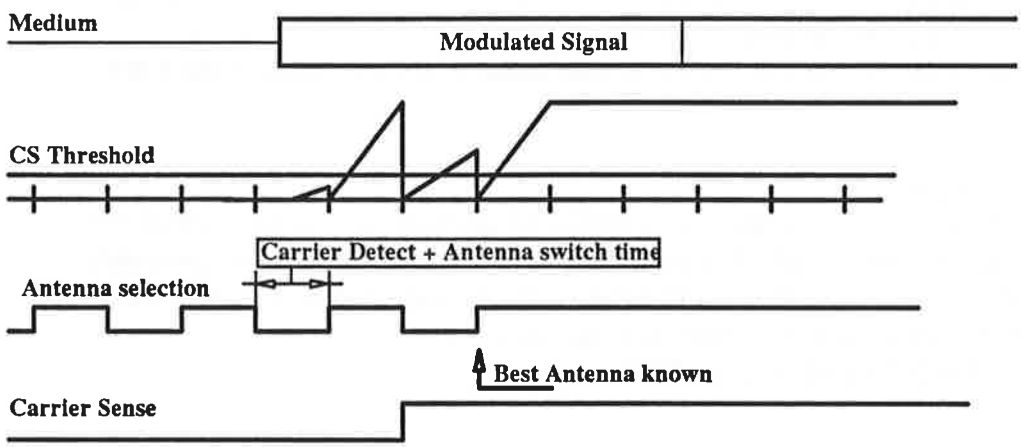
- Carrier Detect response time
- Antenna slot time
- Tx-Rx turnaround time
- Rx-Tx turnaround time
- Preamble length

Carrier Detect response time:
This response time is important to achieve a good medium efficiency. As explained above, it has effect on the total slotting time specification that will affect the backoff window, and collision probability. This should be the time required to allow detection of the incomming signal at the minimum receiver sensitivity level. The effective time this takes will be

dependent on the antenna diversity phase, as will be discussed in the next section. ***It should not include the Rx-Tx switching time*** as currently specified in the PHY.

Antenna slot time:
This parameter is not yet provided in the PHY template. However it will be applicable to antenna diversity implementations, that will switch between two antenna's. An example of this is given in [2]. In the idle mode, the receiver will continuously monitor the medium for modulated signal. In an antenna switch diversity system this is likely done by switching between antenna's at a rate that matches with the Carrier detection time.

A receiver will switch to an antenna, monitor the signal for a duration, that is adequate to detect the presense of modulated signal (the Carrier Sense Response time), and switch to the alternative antenna, to check monitor the (modulated) signal level. A receiver state machine will use the results to determine which antenna is to be selected for further processing of the received signal if any has been detected. This state machine should send a CS indication to the MAC, as soon as a proper signal level has been detected on either one of the antenna's.



Antenna Slotting effects on CS

The antenna switching phenomena will cause a variable Carrier Sense response time, that may depend on the incomming signal level, and the synchronization between the start of the transmission and the antenna slotting mechanism in the receiver.
It will be advantagous to synchronize this slotting mechanism on the end of an incomming signal, in such a way that a minimum IFS (Inter Frame Space) can be achieved between for instance the transmit frame and a responding Ack.

The above shows that the Carrier Detect response time is part of the slot time,which would be applicable for antenna diversity based receivers. Receivers without antenna diversity would only provide the Carrier Detact responce time.
The definition of the slot time should be:

Carrier detect time + max(Rx-Tx turn-on time or Antenna switch time)

In a single VCO transceiver architecture the Rx-Tx turn-on time and Antenna switch time can be very short and are likely in the same range.

Tx-Rx Turnaround time:
This parameter will determine how fast a receiver is able to receive an incomming signal with the specified detection threshold. For the protocol this parameter plus the medium propagation delay may determine what the minimum IFS time would be, after which the Ack signal can be properly received.
This parameter will likely be larger then the Rx-Tx turnaround time, in an architecture where no VCO switching is required.
Unlike the current approach in the PHY template, this parameter should be specified such that it does not include any preamble time.

Rx-Tx Turnaround time:
This parameter and will determine how fast energy is being transmitted after the transmit command is being issued by the MAC (change PHY template definition).
As discussed above, this parameter should be made as short as possible, and is more important then the length of the preamble time.
The template definition of this parameter should change so as to exclude the PHY preamble time.

PHY preamble length:
This length (in symbols) will determine the duration of the receiver synchronization time, and represents the PHY overhead. This parameter should be the length of the preamble from the start of the signal until the first MAC data bit. As such it should include the start delimiter and Phys Signalling Field (PSF) as is introduced in [3].
This parameter should be added to the PHY template.

Conclusion:
The importance of the Rx-Tx turnaround time (and vice versa) for the efficiency of a MAC protocol has been shown. It is further identified as a very important migration parameter. The tradeoffs between different transceiver architectures and the resulting throughput performance have been discussed. The conclusion is that we should stress the trunaround time parameters of the PHY standard as much as possible, even when this would limit the radio architectures that can be used for the implementation.
Further the important PHY parameters and their definitions have been addressed, which will have affect on the MAC efficiency.

References:
[1] Pablo Brenner, LANNAIR Ltd. "The importance of the tx-rx switching time on the MAC protocol". Doc P802.11-93/109.
[2] Jan Boer, NCR: "Proposal for a 2 Mbit/s DSSS PHY". Doc P802.11-93/37.
[3] Wim Diepstraten, NCR: "The Need for MAC Data delimiters in the PHY ". Doc P802.11-93/146.

[4] Nathan Silberman/Jan Boer: "Draft proposal for a Frequency Hopping and Direct Sequence Spread Spectrum PHY standard". Doc: IEEE P802.11-93/83r1.