IEEE 802.11
Wireless Access Method and Physical Specification

Title: **Carrier Sense with Diversity Model for FH PHY**

Date: March 7, 1994

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Abstract

The 802.11 standard for wireless LANs must include a carrier sense model which can be proven to meet the requirements of the committee. This paper first discusses the requirements and constraints on carrier sense and diversity. A summary of lock detector performance simulation and analyses will be presented. Three algorithms for carrier sense with diversity are presented that will meet the requirements given the realizable performance of the detector. Finally, values for carrier sense and diversity requirements are presented for discussion.

Introduction

Carrier sense is required for two basic functions of the CSMA/CA protocol: to detect the presence of a signal to receive, and to determine when the channel is clear to transmit. Antenna diversity increases the probability of sensing and being able to receive a signal. The two functions are interlaced in requirements, parameters, and timing and thus must be considered together.

Carrier Sense Requirement Parameters

The key requirement parameters for carrier sense and diversity are listed below with desired values. Proposed requirement values that take into account the performance of realizable detectors and algorithms are contained in the table at the end of this paper.

Probability of Detection (P_{det}) in preamble - highest possible

We want the carrier sense to operate down to the lowest SNR possible. Higher sensitivity in the carrier sense reduces the hidden terminal problem. This should be as high as possible because this leads into receiving the packet. Under normal circumstances, the terminal should be able to detect the preamble if it can hear the packet at all.

Probability of Detection (P_{det}) with random data - very high

Random data can have low transition densities. This may occur when waking up from sleep mode in the middle of a packet or in certain conditions of collision between two other transmitters. These are limited conditions and thus P_{det} with random data does not have to be as high as P_{det} in the preamble.

Probability of False Alarm (P_{fa}) with noise only - lowest possible

We want to avoid false indications of carrier sense because that reduces a single terminal's throughput. However, the system throughput and offered load are not significantly affected since there is no additional usage of the medium due to a false alarm in any given terminal. The lock detector should be combined with an RSSI measurement - the lock detector test should only be used if the RSSI is above the threshold. This avoids frequent false alarms in a quiet environment.

Probability of Detection (P_{det}) with opposite PHY - TBD

Probability of False Alarm (P_{fa}) with TBD interferers - TBD

Positive carrier sense response time - shortest possible

This is defined as the maximum time from the start of a packet to when the carrier sense indication goes to "busy." The longer the carrier sense observation window, the more reliable the carrier sense can be. On the other hand, shorter carrier sense times mean lower probability of collisions, shorter preambles, and less overhead.

Receive antenna selection time - shortest possible

This is defined as the maximum time from the start of a packet to when the antenna is selected and the receiver has settled and outputting valid bits. The maximum antenna selection time defines the preamble length.

RSSI false alarm reset time - shortest possible

Most methods use a combination of RSSI and some form of clock lock detection. If the RSSI crosses the minimum signal threshold because of increased noise or interference, it would be desirable to have the radio return to the diversity scanning mode as soon as possible.

Constraints

There are three basic constraints. All are related to the allowed carrier sense time and would disappear if there was an infinite amount of time allotted.

Propagation and settling time through the receiver and demodulator

This is typically 5 - 10 μs. This affects all requirement parameters but especially the preamble detection. Preamble can be determined fairly quickly and 10 μs is a lot of time relative to the amount needed.

Time required to get a sufficient number of transitions in random data with a high probability

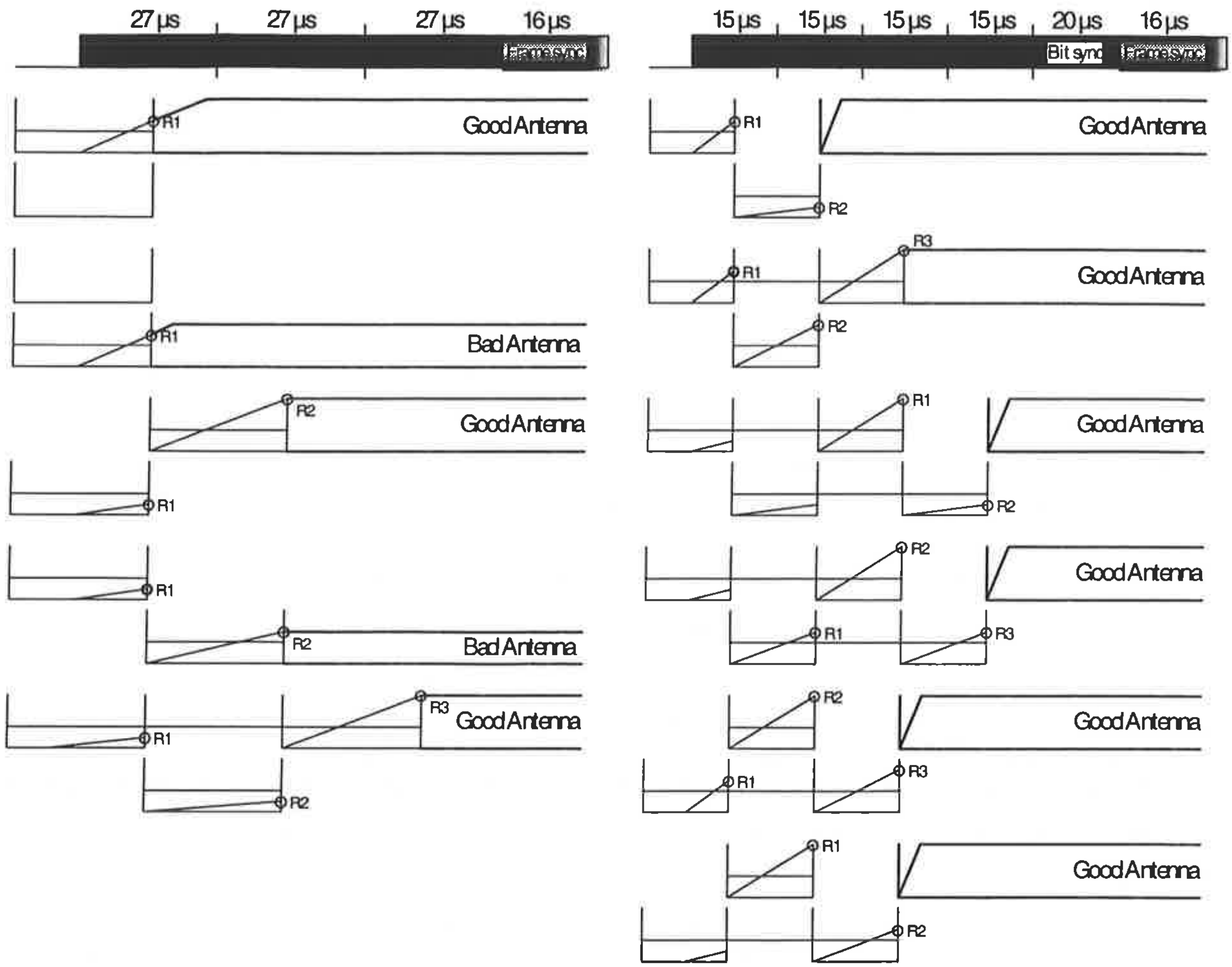
"Sufficient" is determined by the reliability desired in distinguishing random data from noise. With low numbers of transitions, it is very difficult to distinguish noise from random data. Because the need to carrier sense in the middle of a packet occurs in limited conditions, additional carrier sense windows that the MAC might be required to wait in these conditions would effectively extend the time available to observe more transitions.

Number of times the diversity antennas must be toggled to carrier sense and select an antenna

For reliable carrier sense, the preamble must allow for a minimum of three carrier sense windows to ensure that the good antenna will see at least one full period of preamble given the uncertainty in packet start time relative to the antenna switching times. However, for selecting an antenna, there are two basic selection methods. Figure 1 illustrates both methods under various conditions of packet start time vs. antenna selection, power registered on good and bad antennas, and partial and full signal observation windows.

The first method selects the "first" antenna that has sufficient signal power and quality to lock to. This requires up to three windows given the unknown packet start time. This is because the good antenna may get only a partial burst or the bad antenna may be selected at the beginning of the packet. With this method, the third window of carrier sense will also be the bit sync window since the antenna is not switched once a selection is made.

The second method selects the "best" antenna which requires a maximum of five windows - four for carrier sense and the fifth for final bit sync on the selected antenna.



(a) (b)

Figure 1. Antenna selection methods. (a) Selects the first antenna with sufficient signal power and quality to lock to. (b) Selects the best antenna.

Lock Detector Performance

Analysis and simulations were performed to determine the typical detection and false alarm probabilities of the lock detector in preamble, random data, and noise. While it is not the purpose of this paper to present the detailed methodology, design, or results of the simulation, a summary of the results will be useful for comparison with other submissions and for eventual progress toward an accepted carrier sense model.

Figure 2 shows typical waveforms with preamble, random data, and noise. The measurement windows where data was settled was 10, 20, and 40 μs.

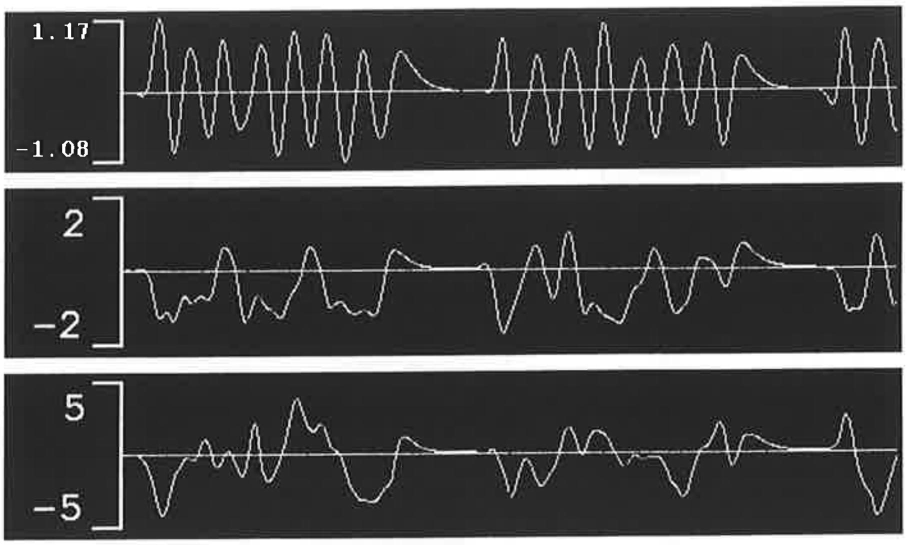


Figure 2. Representative simulation waveforms of preamble, random data, and noise

The results of the simulations are summarized in Figure 3. The results varied as a function of parameters optimized for P_{det}[Random Data] or P_{fa}[Noise] and initial frequency offset. The significance of the results are that P_{fa}[Noise] is in the 0.04 range (1 out of 25 incorrect) and P_{det}[Random Data] is in the 0.85 range (1 out of 7 incorrect) for windows _20 μs.

Measurement Window	P_{det}[Preamble]	P_{det}[Random Data]	P_{fa}[Noise]
10 μs	0.96 - 0.99	0.65 - 0.85	0.05 - 0.12
20 μs	0.97 - >0.99	0.85 - 0.91	0.02 - 0.04
40 μs	>0.99	0.97 - 0.99	<0.01 - 0.02

Figure 3. Summary of Detector Performance Simulation

Viable Carrier Sense State Diagrams

Given the 80 μs time available in the preamble length voted in the FH PHY sub-group, there are three basic carrier sense algorithms which would be possible.

The first and simplest method illustrated in Figure 4 selects the first antenna with sufficient power and quality to lock to. Dividing the 80 μs into three equal windows gives about 27 μs per window. Lock check can be done at each window. P_{det}[Preamble] is good and P_{det}[Random Data] and P_{fa}[Noise] are fair.

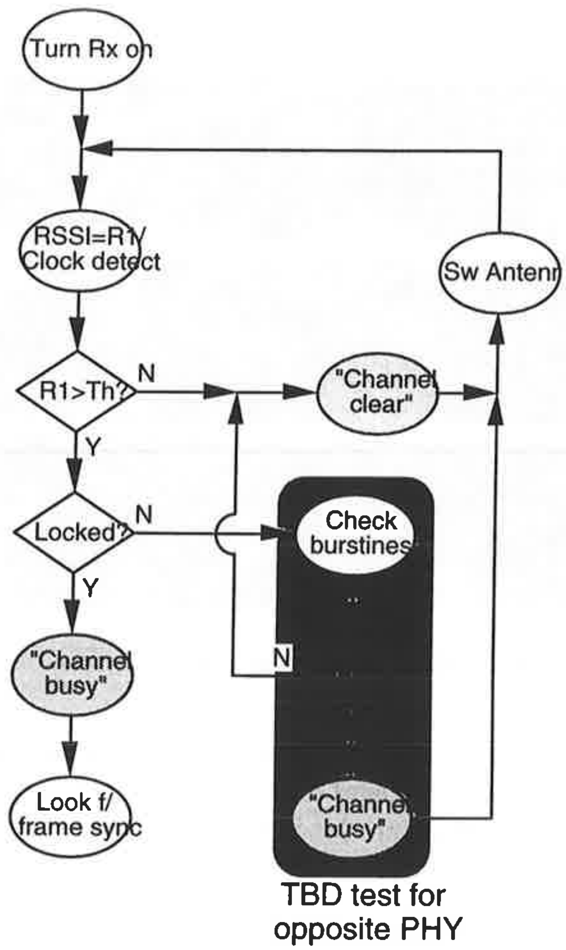


Figure 4. Carrier Sense/Diversity algorithm selecting first antenna with sufficient power and quality to lock to

The second method illustrated in Figure 5 selects the best antenna based on RSSI only, and then checks for clock lock in a longer period. This method will use about 10 to 15 μs per RSSI/antenna selection window and leave about 20 to 40 μs left for clock lock. This method can have a long observation window and good detection performance, but also has the longest delay between packet start and positive carrier sense indication. Also, if the RSSI gave a false alarm, this method would have the longest delay before going back into diversity scanning mode.

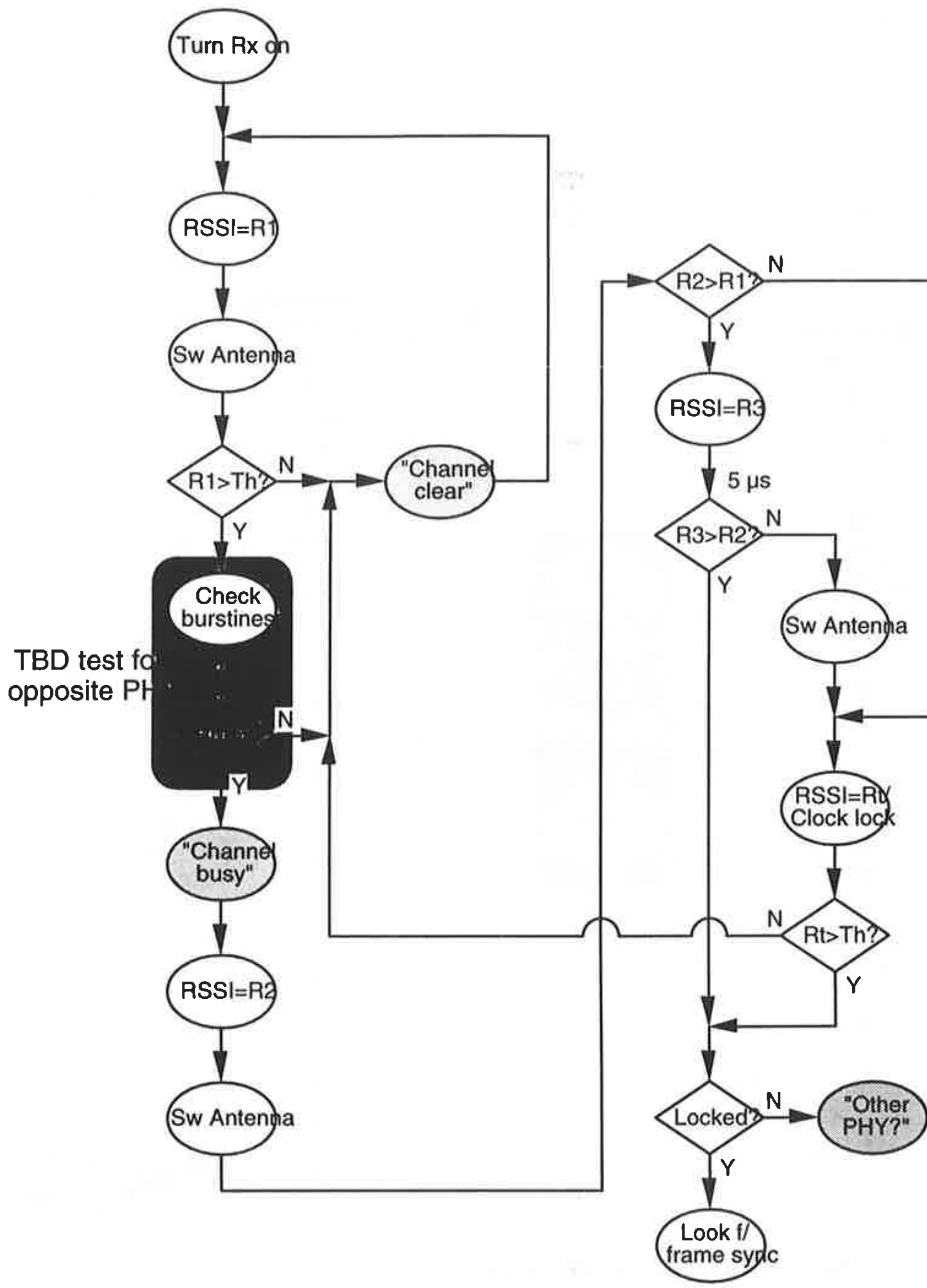


Figure 5. Carrier Sense/Diversity algorithm selecting antenna with largest RSSI and checking lock after antenna selection

The third method illustrated in Figure 6 selects the best antenna based on both RSSI and clock lock. The windows would most likely be evenly divided into the 80 µs to give 16 µs per window. This is feasible only if the receiver settling delay is <6 µs. Response time and P_{det}[Preamble] is good but P_{det}[Random Data] and P_{fa}[Noise] are poor.

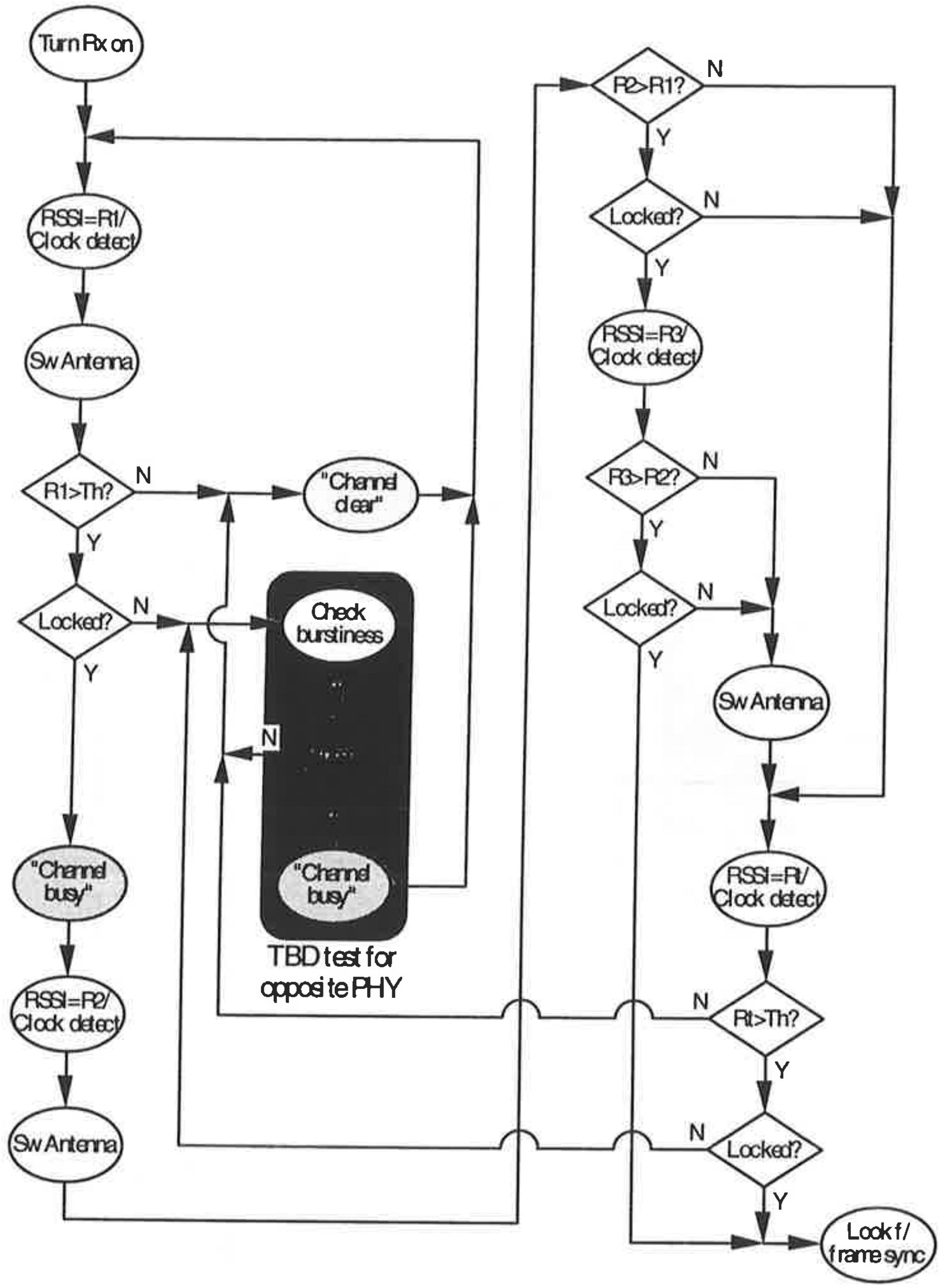


Figure 6. Carrier Sense/Diversity algorithm selecting best antenna with clock lock check at each antenna

Proposed Carrier Sense Requirements

I propose the carrier sense requirements in Figure 7 - both parameters and values - as a starting point for discussion in the FH PHY.

Parameter	Requirement	Allocation	Comment

Pdet[preamble]	0.99 /antenna		Does not penalize having diversity antennas
Pdet[random data]	0.97 for 1 out of 2 antennas	0.85 /antenna	Requires MAC to look _2 windows on power up and collision suspected
Pfa[noise]	0.02		Only during non-power up mode
Pdet[opposite PHY]	TBD		
Pdet[TBD interferer]	TBD		
Positive carrier sense response time	_ 40 µs		
Antenna selection time	_ 80 µs		Defines preamble length; already voted in FH PHY
RSSI false alarm reset time	_ 40 µs		

Figure 7. Proposed Carrier Sense Requirements