IEEE 802.11
Wireless Access Method and Physical Layer Specification

Title: **Proposal For 2.4 GHz Frequency Hop Clear Channel Assessment Process**

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Abstract: A three step Clear Channel Assessment, CCA, process is proposed which has the capability to provide rapid response, under 40 microseconds, with low probability for substantial false deferral delays. The process utilizes Idle Pattern detect for an initial CCA detection. This initial detection provides a transmission deferral command but must be confirmed by reception of a verified length field within a specified length of time or the deferral command is aborted. If the initial deferral decision is confirmed, then the deferral command to the Mac is extended to the expected end of the transmission packet.

Introduction

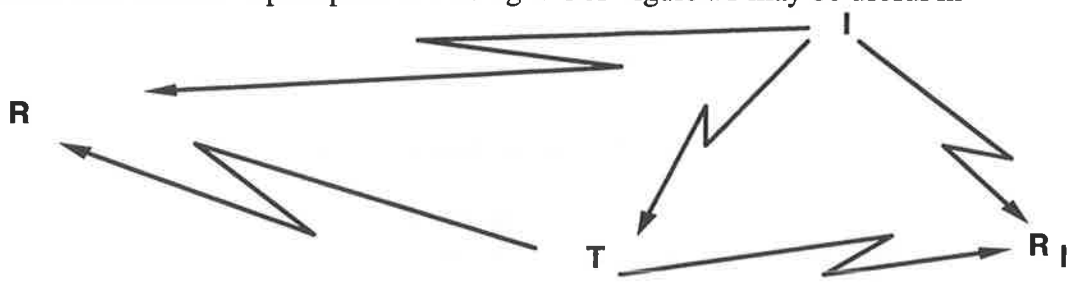
This submission addresses the issue of Clear Channel Assessment, CCA. The CCA process is used by a wireless LAN transceiver to determine if an RF channel is occupied with an RF signal before beginning its own transmission. If the CCA process determines that there is a transmission occupying the RF channel, then the transceiver in question may defer its transmission until later. If the transceiver in question determines that the channel is not in use, then the transceiver is free to begin its transmission. The phrase "may defer" is used to reflect the possibility that the CCA process may be selective in the types of RF signals for which it will defer.

Note: In this paper the CCA process will be viewed as a process where deferral is required only when the signal occupying the channel is an IEEE 802.11 conformant Frequency Hop signal. The author reflects the desired expressed in previous IEEE 802.11 PHY meetings that deferral to RF power of a different origin is undesired in an ISM band, where microwave ovens, for instance, are allowed to operate.

In an RF LAN, the CCA process represents some complex trade-offs that in general lead to less than prefect results. The task at hand is to provide a reasonable compromise.

Overview of CCA

A review of the simple operational diagram of Figure #1 may be useful in



Operational Diagram

Figure #1

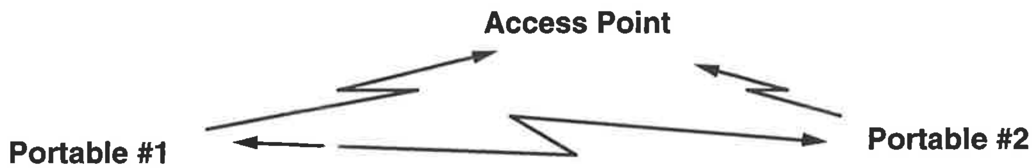
describing and understanding CCA. Four communicating devices are depicted in this diagram, T, R, I and R_I. T is the device contemplating transmission of a packet of data and hence performing CCA. R is the device to which T will transmit. I is the device that may be emitting interference RF power. R_I is the device intending to receive the signal from I assuming that I is a communications transmitter, not an RF heater. Thus, before transmitting its packet, T evaluates the RF channel to determine if I (any I) is likely to interfere with the reception of its signal by R. In addition, a determination is made as to whether it is likely or not that a transmission from T would interfere with the reception of the signal from I by R_I.

If either possibility is likely, then a decision may be made by T to defer transmission because the system designers made the judgment that to defer under specified circumstances will, on the average, lead to faster, more reliable communications for all devices using the communications channel.

There are, in general, fundamental limitations to the CCA task in an RF environment. These were discussed in doc 94/79 submitted by this author in the May 1994 meeting. Most significant of these issues are:

1. Hidden Node Syndrome

Consider two portable transmitters attempting to transmit to an Access Point, as illustrated in Figure #2. The two portable transmitters are on different sides of the



Hidden Node Syndrome

Figure #2

cell. Thus, both portables are within range of the Access Point, but not necessarily within range of each other. If the portables are not within range of each other, then with respect to CCA, they cannot defer to each other.

Conclusion: The CCA function should be as sensitive as practical.

2. CCA Delay Issue

Considering the same physical scenario as depicted in Figure #2, the portables may not defer as desired if the CCA process is too slow. Thus, even though the portables are within range of each other, a lengthy CCA process provides a period where the portables are blind to the existence of transmissions from each other. The CCA process is unable to prevent collisions from occurring in that blind period. Therein lies the weakness to a "header detect only" CCA where the CCA process does not produce a command to the Mac to defer transmission until approximately 200 microseconds into an interfering packet.

Conclusion: The CCA process should be as fast as practical.

3. False Deferral

If the CCA process is too sensitive, sensitive to unmodulated RF, too fast, etc., it may be subject to excessive false deferral.

Conclusion: The CCA process should not be vulnerable to excessive rates of false alarm.

CCA Proposal

What is proposed here is a three step CCA process consistent with the conclusions listed above. The CCA will operate by sending a signal, CCA_Busy, to the Mac which will cause the Mac to delay the initiation of a transmission.

The three step CCA process is:

1. Minimum Monitoring Period, MMP

If a transceiver has been in a non-receive mode, "called sleep", it must monitor the channel for at least as long as the maximum length packet or fragment that is expected on the RF channel. This entity is called Physical Layer Convergence Procedure Frame Format, PLCP, in Paragraph 3.3 of the March 1994 edition of the Frequency Hop Physical Layer Draft Specification, Doc:

94/068. This minimum monitoring period, MMP, will allow the modulation sensitive CCA function to search for header specific aspects of the packet, i.e., the CCA does not need to be sensitive to random data signals that occur during the body of the packet. The delay in communications imposed by MMP occurs only upon wake up when there is a packet to be transmitted. This delay is not an accumulative issue.

2. 1,0 Idle Pattern Detect, CCA_Detect

The proposed CCA will monitor incoming signals for the 1,0 Idle Pattern which is the initial segment of all compliant IEEE 802.11 Frequency Hop data packets. The CCA specification will call for that detection process, CCA_Detect, to be made within 40 microsecond of the beginning of the Idle Pattern as depicted in Figure #3. The rapid response time satisfies the issue of avoiding excessive delay addressed in #2 above. This decision causes the CCA_Busy line to switch from low to high.

3. Packet Length and CRC Detection, CCA Confirm

After being triggered by the CCA_Detect signal, the CCA_Busy will remain high for only a limited period of time, T_1*. If the input RF signal is a compliant IEEE 802.11 Frequency Hop data packet, detection of the unique word, the length field and CRC code verifying the correctness of the decoded length field will result in a high CCA_Confirm within T_1. If this occurs, the CCA_Busy command will be extended to the expected length of the received data packet. If the CCA_Confirm command is not received with a specific period of time, T_1, from the initial CCA_Detect command, then the CCA_Busy command to the Mac will be aborted. If the length field is correctly received within T_1, then the CCA_Busy command will remain high until at least 8 microseconds after the end of the Mac data field as depicted in Figure #3 &#4.

* T_1 in microsec = (80)(IP) + 16(UW) + X(PSF) +8
PSF = Phy Signaling Field

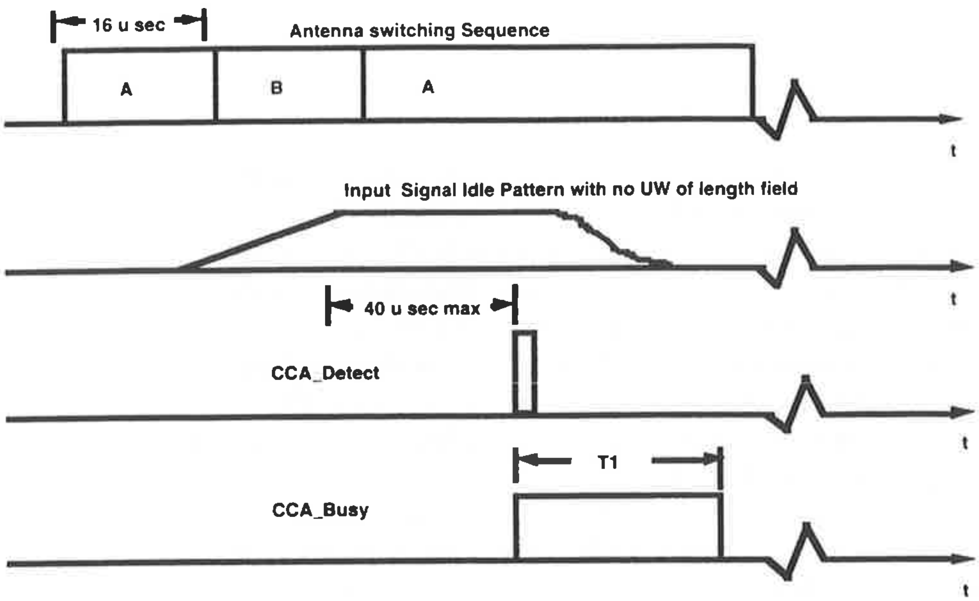


Figure #3: CCA Process with Idle Pattern not followed by length field

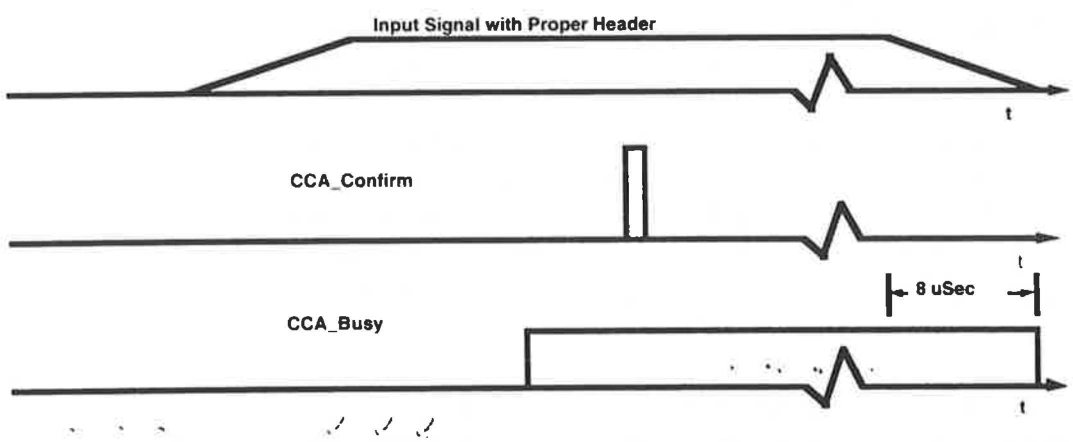


Figure #4: CCA Process with Idle Pattern followed by verified length field

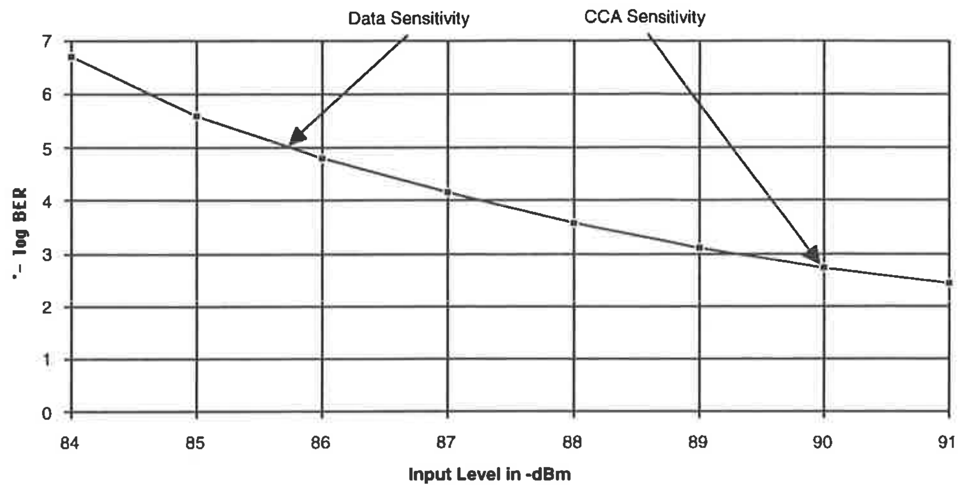
Discussion

The proposed CCA process is an aggressive approach to meet the rapid response requirement without sacrificing performance or important capabilities such as the antenna diversity option which is viewed as significant in providing the coverage desired. As discussed in Socci's submissions, 93/72 and 93/148, diversity is readily accomplished by switching antennas. Considering that there might be two antennas, a decision based on Idle Pattern with the proposed CCA process would be available within 40 bit periods of the start of the Idle Pattern regardless of the initial state of antenna selection sequence. Thus, the CCA specification would require the CCA_Busy line to be switched to high within 40 microseconds of the application of the test signal.

The Idle Pattern sensing aspect of the CCA process is dependent on the existence of clock signal power modulating the RF carrier and is therefore less prone to false alarm triggering than a CCA based only on the detection of RF power. False alarms signal may nonetheless be experienced. To minimize the impact of such false alarms on deferral delays, the initial Idle Pattern detection, CCA_Detect, must be confirmed by detection of the unique word, the length field and a CRC verifying the length field within T_1. Figure #3 &#4 summarizes those parameters. The potential for false alarm on the confirmation, CCA_Confirm, aspect of the CCA process is nil. This addresses the need to minimize the impact of CCA false alarms.

The final important aspect of the CCA process is the RF sensitivity. Figure #5 represents actual data from a receiver compliant to the modulation format so far developed by IEEE 802.11. This data is based on ±164 KHz deviation with a Gaussian modulation filter having a 3 dB cutoff at 500 KHz. This receiver has a BER of 10^{-5} at -85.8 dBm, which is nearly 2 dB below the proposed specification for sensitivity in document 93/79, of -84 dBm. (This document allows sensitivity of -82 dBm at the band edges.) Detection of the unique word and length field with CRC requires the correct reception of 48 bits (estimated). In order to achieve this detection 9 tries out of 10, a reasonable sensitivity level success rate for CCA, a bit error rate of 1 error per 480 bits or 2×10^{-3} BER is required. (Note: log0.002 = 2.7.) This is called CCA Sensitivity in Figure #5 below. According to this data, CCA Sensitivity is more than 4 dB below 10^{-5} BER or Data Sensitivity. It is therefore proposed that CCA sensitivity for RF sensitivity be -88 dBm, achieved with 90% probability.

Figure #5 **BER Sensitivity of a Test Receiver**



CCA Conformance Testing

The goal of conformance testing with respect to the CCA proposal would be to assure that:

1. The Idle Pattern detection, CCA_Detect, occurs within 40 microsecond when a sensitivity level signal is applied to all RF inputs.
2. If the Idle Pattern that initiated the CCA_Detect command is not followed by the unique word and verified length field, then the CCA_Busy command is held high for at least T_1 microseconds.
3. If the unique word, length field and CRC are properly received within the appropriate time period, then the CCA_Busy command is extend to the end of the MDU period plus 8 microseconds.
4. That all of the above is accomplished with a 90% probability of success at a signal level, RF_j in Figure #6, of -88 dBm or less.

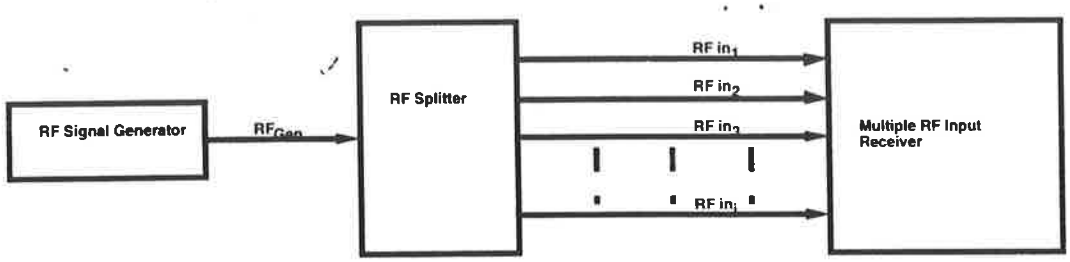


Figure #6 Definition of RF input level for receivers with multiple inputs