Refinements to the Frequency Hop CCA Criteria

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Abstract:

It is the author's contention that the current Frequency Hop CCA specification is flawed and if not amended will undermine the utility of the standard. The concern is relative to the CCA requirement to defer if pseudorandom data is present.

Introduction

The scope of this submission is to first identify the aspect of the CCA related text of the current draft that the author recommends be changed, to discuses the reasons that lead to that conclusion that it should be changed and then to propose new wording.

Current Text

For completeness, the text of 10.3.3.2.1 is repeated below along with section 10.6.23.

10.3.3.2.1 Carrier Sense/Clear Channel Assessment State Machine

The carrier sense/clear channel assessment (CS/CCA) state machine is shown in Figure 10-9. The PLCP shall perform a CS/CCA assessment on a minimum of one antenna within a contention backoff slot time of 50 μs. The PLCP shall be capable of detecting within the slot time an FH PHY conformant signal which is received at the selected antenna up to 20 μs after the start of the slot time with the detection performance specified in section 10.6.23. Section 10.6.23 specifies detection performance with zero-one sync patterns and with random data patterns. If a start of a transmission is asynchronous with the BSS and arrives after the start of the slot but at least 16 usec prior to the end of the slot, the PLCP shall indicate a busy channel prior to the end of the slot time with the detection performance specified in section 10.6.23. The CCA indication immediately prior to transmission shall be performed on an antenna with essentially the same free space gain and gain pattern as the antenna to be used for transmission. The method of determining CS/CCA is unspecified except for the detection performance of a conformant method as specified in section 10.6.23.

If a *PHY_DATA.request (Start_of_Data, TXVECTOR)* is received, the CS/CCA procedure shall exit to the transmit procedure. If a *PHY_DATA.request(End_of_Activity, NULL)* is received, the PLCP shall reset all relevant CS/CCA assessment timers to the state appropriate for the end of a complete received frame. This service primitive is generated by the MAC at the end of a NAV period.

If a CS/CCA assessment returns a channel idle result, the PHY shall send a *PHY_DATA.indicate (End_of_Activity, NULL)* to the MAC.

If a CS/CCA assessment returns a channel busy result, the PHY shall send a *PHY_DATA.indicate(Start_of_Activity, NULL)* to the MAC. Upon a channel busy assessment, the PLCP shall stop any antenna switching prior to the earliest possible arrival time of the start frame delimiter (SFD) and detect a valid SFD if received. If a valid SFD is detected, the CS/CCA procedure shall exit to the receive procedure. The PLCP shall dwell and search for the SFD for a minimum period longer than the latest arrival time of the SFD. Indication of a busy channel does not necessarily lead to the successful reception of a frame.

Upon exiting the CS/CCA procedure to receive a frame, the last indication of CS/CCA was BUSY. The indication remains BUSY when returning from the receive procedure until the first CS/CCA assessment is performed and determines that the channel is IDLE.

The countdown timer may be a non-zero value when returning from the receive procedure if a signal in the process of being received was lost prior to the end as positively indicated in the length field of a valid PLCP header. The countdown timer shall be used to force the CS/CCA indication to remain in the BUSY state until the predicted end of the frame regardless of actual CS/CCA indications. However, if the CS/CCA procedure indicates the start of a new frame within the countdown timer period, it is possible to transition to the receive procedure prior to the end of the countdown timer period. When a non-zero countdown timer reaches zero, the PLCP shall reset all relevant CS/CCA assessment timers to the state appropriate for the end of a complete received frame. The initial value of the countdown timer upon entry of the CS/CCA procedure from power up or PHY reset is unspecified.

10.6.23 Clear Channel Assessment Power Threshold

The PHY shall, in the presence of any 802.11 compliant FH PMD signal above -85 dBm, signal busy with a 90% probability in detection of the preamble within the CCA assessment window. The PHY shall, in the presence of any 802.11 compliant FH PMD signal above -65 dBm, signal busy with a 70% probability for detection of random data within the CCA assessment window. This specification applies to a PMD operating with a nominal EIRP of <100mW. A compliant PMD operating at a nominal output power greater than 100mW shall use the following equation to define the CCA threshold. Pt represents Transmit Power.

CCA Threshold (Preamble) =-85dBm -(5*log10(Pt/100mW))dBm

CCA Threshold (Random Data) = CCA Threshold (Preamble) + 20 dB

Reference to Draft Text Completed......

Discussion

The author wishes to address two problems with this section of the draft standard. Both relate to the first paragraph of section 10.3.3.2 cited above.

Problem # 1

Note the following sentence from the this section of the draft text:

"Section 10.6.23 specifies detection performance with zero-one sync patterns and with random data patterns." The author focuses particularly on the "random data" aspect and has concluded that this requirement is difficult to implement, provides only very marginal benefit to the CCA detection process, and seriously degrades the false detection probability of equipment compliant to the standard.

What this requirement speaks to is depicted in Figure 1, as the signal profile received by a station, call it station #3. Here, Signal A, which was transmitted by station #1, ends as shown but there is another signal, Signal B, which was transmitted by station #2, is recovered following the end of Signal A but at lower magnitude. Signal B only becomes apparent after Signal A ends. The requirement in question refers to the CCA function to defer to the weaker signal, Signal B, if it is above -65 dBm.

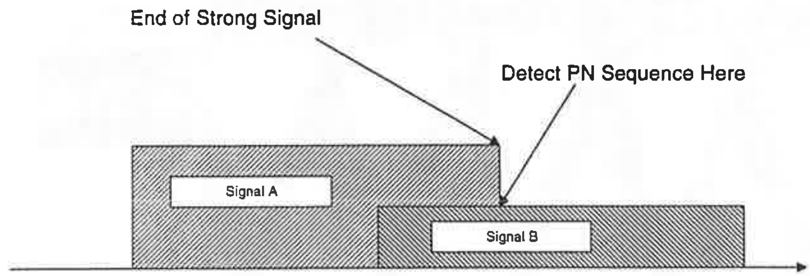


Figure #1

Note that since Signal B starts while Signal A is on the air, the receiver in question, the receiver of station #3, is not able to monitor the preamble of Signal B. In order for receiver #3 to perform a CCA decision on Signal B, it must evaluate Signal B after the preamble period has long since been completed. Hence, the CCA decision must be based on:

signal amplitude only, or

signal amplitude in combination with pattern recognition.

It is the author's contention that reliable recognition of the wide range of patterns that might illegitimately result is, at best, difficult and hence practical, moderate cost, receivers will need to rely on amplitude only for CCA detection.

CCA Based on Amplitude Only

CCA based on amplitude only will result in deferral to transmission from such sources as microwave ovens and non IEEE 802.11 Frequency Hop transmissions. It has been the conclusion of the Frequency Hop group that this is a highly undesirable result. For instance, if an installation of a WLAN system in a faculty equipped with microwave ovens has been careful configured so as to be fully operational in spite of microwave oven interference, the IEEE 802.11 CCA rule might needlessly prevent the system from operating. In addition, the rule in question provides the mean for completing systems to be designed so as to prevent IEEE 802.11 Frequency Hoppers from operating.

CCA Based on a Combination of Both Amplitude and Pattern Recognition

A CCA system based on the combination of both signal amplitude and recognition of distinctive IEEE 802.11 Frequency Hop signal patterns would be effective in preventing the system blockage that would be associated with "amplitude only" form of CCA. Of that there is little doubt. The issue, however, is the technical difficulty associated with effective signal pattern recognition. Pattern recognition requires the recognition of:

"on channel" two level, 1 Mb/s, 802.11 Frequency Hop signals

"on channel" four level, 2 Mb/s, 802.11 Frequency Hop signals

The discriminator output of a receiver intended for the reception of two level signals is depicted is Figure 2. A comparable figure depicting output waveform corresponding to a four level input is not available, but extrapolation of the result illustrated in Figure 2 would indicate that the eye would be virtually closed.

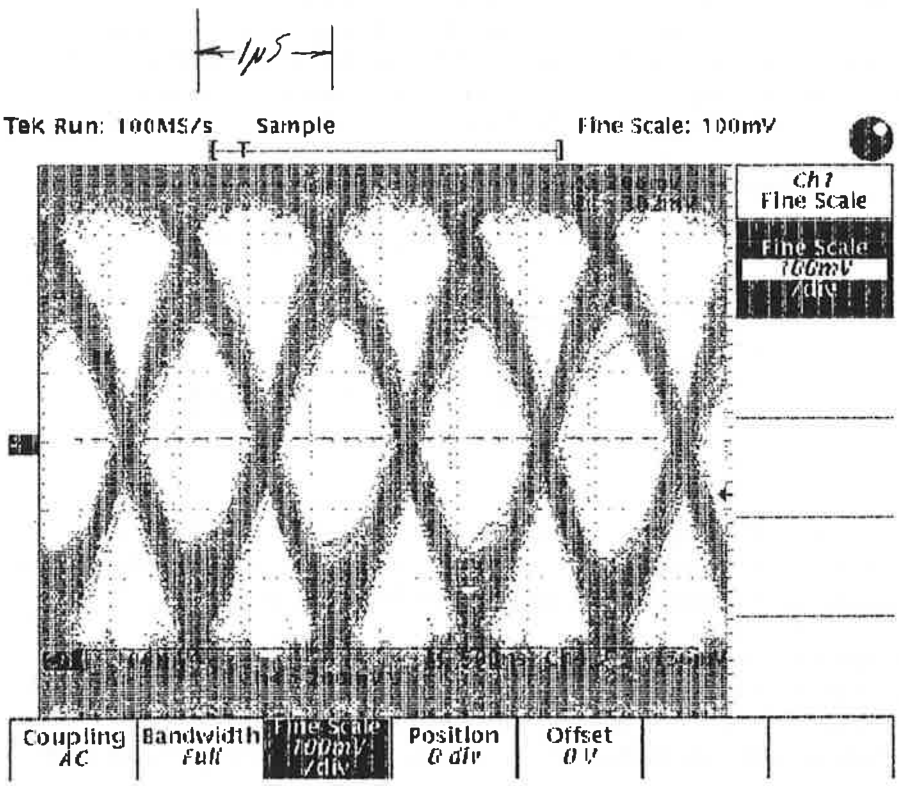


Figure #2

In a fully functional system one might expect signals, not only "on channel" signals, but also "adjacent channels" signal from both two level and four level IEEE 802.11 Frequency Hop sources. Figure 3 depicts the discriminator output, with dc removed, resulting from a two level signal on the "adjacent channel". Note the strong 1 MHz content. Note also the small eye opening. How does a simple, low cost, receiver discriminate against this signal, but yet defer to an "on channel" two or four level Freq Hop IEEE 802.11 signal?

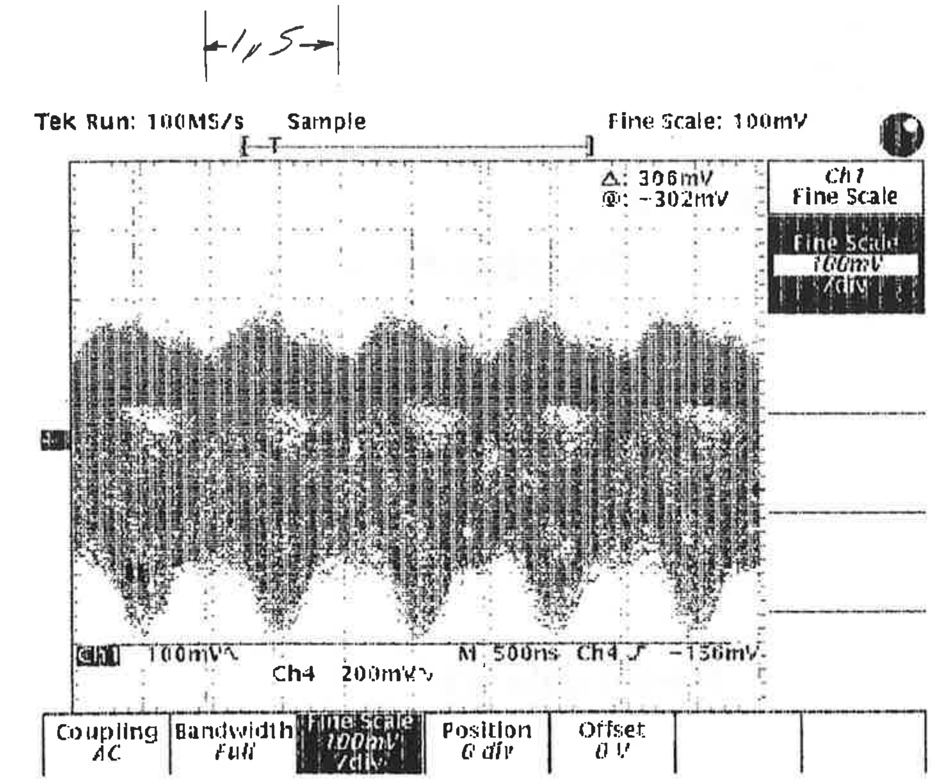


Figure #3

What feature of the two level and four level signals is distinctive enough for a simple, low cost, receiver to positively identify either waveform?

The answer escapes the author.

The author concludes, therefore, that to implement the pseudorandom aspect of the CCA requirement means a choice between increased cost (and power consumption) or high vulnerability to false deferral.

Thus, problem #1 is identified. The requirement for the Frequency Hop PHY to defer to a pseudorandom data is a problem in terms of requiring either:

high cost and high power consumption circuits, or
excessive deferrals.

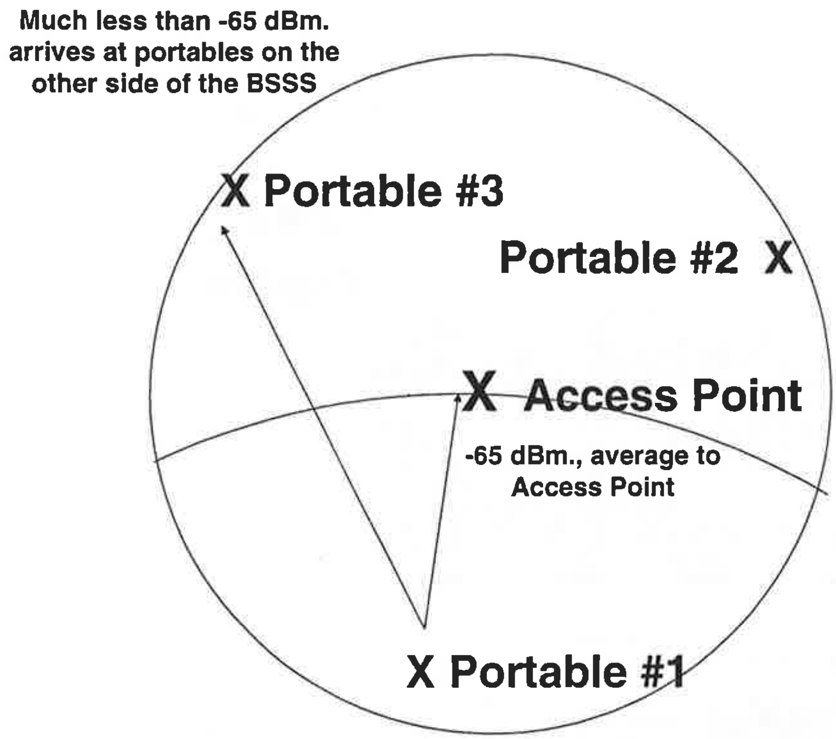
Before proposing to eliminate this requirement, it is appropriate to discuss where the pseudorandom requirement provides any substantial benefit to system operation.

Is There System Benefit to the Pseudorandom CCA Requirement?

The above section clearly illustrates that there is a cost or unit performance penalty to the pseudorandom aspect of the CCA requirement. Is there a system benefit? If there is, it is very small and perhaps actually negative.

Two situations are instructive in order to evaluate the potential benefit of the pseudorandom CCA function.

Case #1
In case #1 all the stations of concern belong to the same BSS as illustrated in Figure #4.



BSS
One Access Point and Three Portables

Figure #4

In this situation, it is reasonable to assume that if the Access Point is transmitting, all the associated portables, i.e., all other stations in the BSS will receive the Access Point signal. With such a result, it is unlikely that the interference phenomena depicted in Figure #1 will occur. If, however, one of the Portable stations is transmitting, it is quite likely that some Portables in the same BSS will not receive Signal A, as in Figure #1, at sufficient strength to trigger the initial aspect of the CCA process, that is, the detection of the preamble. Thus, if Portable #1 transmits Signal A as in Figure #1, Portable #2 may not receive the preamble and therefore begin transmission of Signal B in Figure #1 before Signal A is completed. We now have a scenario for the development of the situation depicted in Figure #1. This might be the situation seen by Portable #3 in Figure #4. The value or potential benefit of the pseudorandom aspect of the CCA criteria is that Portable #3 is less likely to cause a third dimension of interference to occur.

Is this of any significant value? It would seen that there is not. First, if the situation depicted in Figure #1 is occurring, then the Access Point is already undergoing an interference situation. Reducing the probability of the third level of interference is therefore of small or negligible value.

The basic problem of Case #1 is the hidden node problem which IEEE 802.11 has long been aware. The solution to the hidden node problem is the RTS/CTS format which alerts all stations in a BSS that a communications sequence is about to occur and collision is avoided through a Mac process. This is the correct solution to the scenario that the pseudorandom aspect of the CCA requirement addresses.

Case #2
If one considers a facility equipped with multiple BSS's, one then questions the CCA aspect of deferral to transmission from other BSS's. With respect to the pseudorandom aspect, however, the condition of concern is a possible signal from a transmitter in a different BSS which is both "on channel" and of rather high strength. Since different BSS's will use different hop patterns, cochannel operation will only occur about 1.5% of the time. When one considers the signal strength requirement, -65 dBm., in combination with the possibility for cochannel operation, the scenario of Case #2 is slight at best.

Thus, the conclusion of the scenario of case #2, based on the dual requirement for cochannel operation and high signal strength, is that the value of the pseudorandom aspect of the CCA criteria is extremely small, if any.

If it is of no advantage, then is it possible that the pseudorandom aspect of the CCA criteria is an actual burden to system operation? It appears that the potential benefit of the pseudorandom aspect of CCA is extremely small even in scenarios configured to demonstrate its advantage. Since pseudorandom aspect of CCA will under some conditions cause undesirable deferral, it appears as though the pseudorandom aspect of CCA is not only a burden to cost but also to system operation.

Based on this argument the author urges that he pseudorandom aspect of CCA be eliminated. Hence, the following motion is proposed.

Motion: 1
It is moved that the first paragraph of section 10.3.3.2.1 and section 10.6.23 be amended as follows:

From 10.3.3.2.1
"The carrier sense/clear channel assessment (CS/CCA) state machine is shown in Figure 10-9. The PLCP shall perform a CS/CCA assessment on a minimum of one antenna within a contention backoff slot time of 50 μs. The PLCP shall be capable of detecting within the slot time an FH PHY conformant signal which is received at the selected antenna up to 20 μs after the start of the slot time with the detection performance specified in section 10.6.23. Section 10.6.23 specifies detection performance with zero-one sync patterns ~~and with random data patterns~~. If a start of a transmission is asynchronous with the BSS and arrives after the start of the slot but at least 16 usec prior to the end of the slot, the PLCP shall indicate a busy channel prior to the end of the slot time with the detection performance specified in section 10.6.23. The CCA indication immediately prior to transmission shall be performed on an antenna with essentially the same free space gain and gain pattern as the antenna to be used for transmission. The method of determining CS/CCA is unspecified except for the detection performance of a conformant method as specified in section 10.6.23."

From 10.6.23
"The PHY shall, in the presence of any 802.11 compliant FH PMD signal above -85 dBm, signal busy with a 90% probability in detection of the preamble within the CCA assessment window. ~~The PHY shall, in the presence of any 802.11 compliant FH PMD signal above -65 dBm, signal busy with a 70% probability for detection of random data within the CCA assessment window.~~ This specification applies to a PMD operating with a nominal EIRP of <100mW. A compliant PMD operating at a nominal output power greater than 100mW shall use the following equation to define the CCA threshold. Pt represents Transmit Power.

CCA Threshold (Preamble) =-85dBm -(5*log10(Pt/100mW))dBm

CCA Threshold (Random Data) = CCA Threshold (Preamble) + 20 dB"

Problem # 2
Consider the following sentence form the first paragraph

"The PLCP shall be capable of detecting within the slot time an FH PHY conformant signal which is received at the selected antenna up to 20 μs after the start of the slot time with the detection performance specified in section 10.6.23"

This sentence is redundant to the requirement of two sentences down which require "an FH PHY conformant signal" to be detected in 16 uSec. The author recommends that the 20 uSec requirement be removed.

Motion 2
It is moved that the first paragraph of section 10.3.3.2.1 be amended to read as follows:

"The carrier sense/clear channel assessment (CS/CCA) state machine is shown in Figure 10-9. The PLCP shall perform a CS/CCA assessment on a minimum of one antenna within a contention backoff slot time of 50 μs. ~~The PLCP shall be capable of detecting within the slot time an FH PHY conformant signal which is received at the selected antenna up to 20 μs after the start of the slot time with the detection performance specified in section 10.6.23~~. Section 10.6.23 specifies detection performance with zero-one sync patterns and with random data patterns. If a start of a transmission is asynchronous with the BSS and arrives after the start of the slot but at least 16 usec prior to the end of the slot, the PLCP shall indicate a busy channel prior to the end of the slot time with the detection performance specified in section 10.6.23. The CCA indication immediately prior to transmission shall be performed on an antenna with essentially the same free space gain and gain pattern as the antenna to be used for transmission. The method of determining CS/CCA is unspecified except for the detection performance of a conformant method as specified in section 10.6.23."