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The Selection of a Short Preamble for High Performance 802.11 Physical Layer Wireless Local Area Networks

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Abstract

In the process of designing a new physical layer standard for high-speed transmission, it is important that a reasonable trade-off between physical layer overhead and data transmission is achieved. The overhead associated with physical layer transmission of a packet preamble serves two purposes:

- *Estimation of Channel Parameters*
- *Transmission of Network information*

In the case of 802.11, the overhead consists of two components: the PLCP synchronization sequence and the PLCP Header. In the existing 1&2 Mbps DS standard, the duration of the entire preamble, including the header, is 192µs. In a recent submission, [1], a new high-performance preamble of duration 80.7µs was proposed; the proposed preamble incorporates a CCK encoded Header. In this paper we describe the technical issues concerning the encoding of the Header. In particular, it is argued that there are serious drawbacks to a CCK encoded Header. These reasons, which are described and justified in the paper, suggests that the 802.11 standards body adopt a universal high-performance preamble incorporating only Barker encoded data. In the event that this suggestion is not viable, a less desirable, dual preamble specification is described.

1 Introduction

In the process of designing a new physical layer standard for high-speed transmission, it is important that a reasonable trade-off between physical layer overhead and data transmission is achieved. The overhead associated with physical layer transmission of a packet preamble serves two purposes:

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- Transmission of Network information

In the case of 802.11, the overhead consists of two components:

- The PLCP (physical layer convergence protocol) synchronization sequence
- The PLCP Header

In this existing 1&2 Mbps DS standard, the PLCP synchronization sequence consists of 128 bits of SYNC followed by a 16 bit SFD. The PLCP Header is comprised of 48 bits of data consisting of a 1-byte SIGNAL field, a 1-byte SERVICE field, a 2-byte LENGTH field and a 2-byte CRC. The entire synchronization sequence and header are scrambled and transmitted at the 1Mbps rate using the 11-bit Barker code in conjunction with DBPSK modulation. The duration of the entire preamble, including the header, is 192μs.

In a recent submission, [1], a new high-performance preamble of duration 80.7μs was proposed. The proposed preamble incorporates a CCK encoded Header. In this paper we describe the technical issues concerning the encoding of the Header. In particular, it is argued that:

- The CCK Header limits the duration of the time available for effective channel parameter estimation
- The robustness of the CCK Header makes the header information insufficiently reliable in certain situations
- For interoperability within a high-speed network, the preamble of all packets, including the header, must be detectable by all users

For these reasons, which are justified in the following pages, it is suggested that the 802.11 standards body adopt a universal high-performance preamble incorporating only Barker encoded data. In the event that this suggestion is not viable, a less desirable, dual preamble specification is described.

2 Issues in Preamble Design

2.1 The Existing 1 & 2 Mbps Preamble

In the emerging high-speed standard, the existing low-performance PLCP preamble (synchronization sequence & header) is of sufficient length and diversity to achieve the purposes of channel estimation and network information, however, with a high cost in throughput efficiency due to the long, 192μs, duration. For purposes of backward compatibility with the installed base of 1 & 2 Mbps products, it is required that in a mixed speed network, all packets shall be required to use the existing preamble if interoperability is to be maintained.

Figure 1 & 2 shows the throughput efficiency effect of the existing long (192μs) preamble. For short packets, the overhead is quite large. For example, in Figure 1, with 14-byte packets (the smallest packet) the overhead is ~63% (@1 Mbps) and ~78% (@2 Mbps); an overhead smaller than 10% requires a packet of length greater than 200-bytes (@1 Mbps) and greater than 400-bytes (@2 Mbps). With the inclusion of the ACK (acknowledge) packet, the ideal throughput of the system is shown in Figure 2. To achieve 90% of the asymptotic capacity requires 600-byte packets (@1 Mbps) and 1000-byte packets (@2 Mbps).

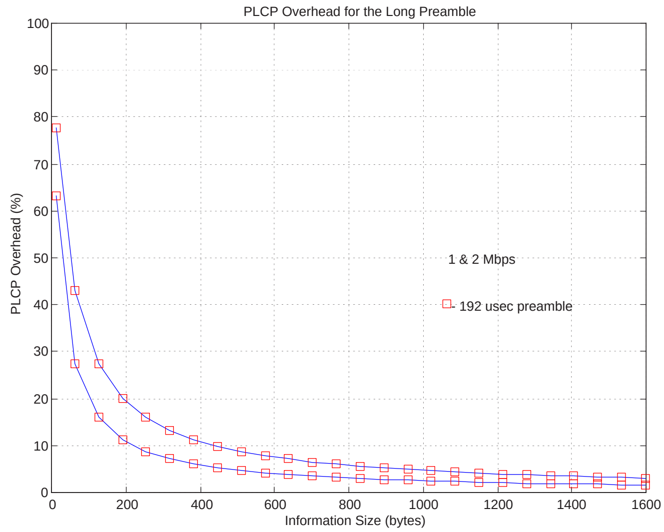

Figure 1: PLCP Overhead for the Long Preamble

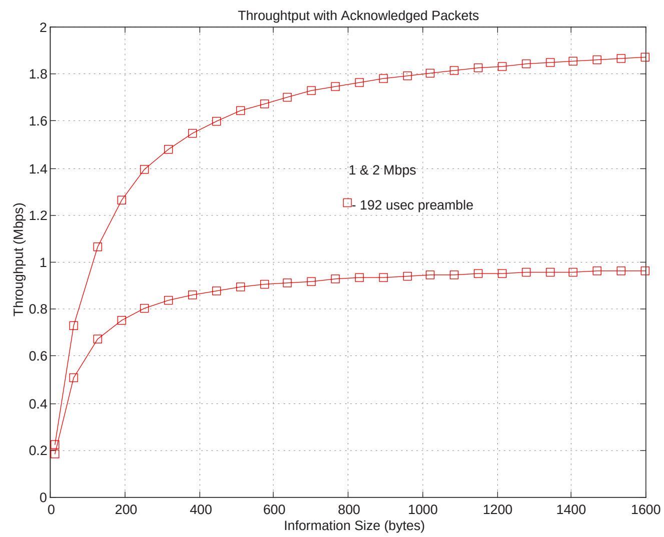

Figure 2: PLCP Throughput with the Long Preamble

2.2 High Performance Preambles

In the future it is reasonable to expect that certain networks will be constructed entirely with high-speed clients. In such a scenario, it is desirable to improve the throughput performance by reducing the high overhead of the existing long (192μs) preamble. In Table 1, a set of viable preamble designs is described. Each preamble consists of three components: a SYNC, a SFD and a Header. In each case, the choice of modulation and code for both the SYNC and SFD field are the existing 1 Mbps Barker coded DBPSK modulation. The length of the SYNC varies from 128μs (the existing long preamble) to 40 μs. The SFD is 16 μs in all cases. In the 1st (the existing) preamble, the Header is encoded with the Barker code and DBPSK (1 Mbps) modulation is used. In the 2nd and 3rd preamble, the Header is encoded with the Barker code with DQPSK (2 Mbps). In the 4th preamble [1], the Header is encoded with the Low-speed CCK code with DQPSK (5.5 Mbps).

	Preamble	SYNC[1] (µs)	SFD[1] (µs)	Header (µs)	Total PLCP Duration (µs)	Channel Estimate Time (µs)
1	LS Barker	128	16	48[1]	192	192
2	LS/HS Barker (S)	40	16	24[2]	80	80
3	LS/HS Barker (L)	56	16	24[2]	96	96
4	LS Barker/ LS CCK	56	16	8.7[3]	80.7	72

Table 1: High-performance Preamble Duration Parameters

In the table, both the total duration of the preamble and the duration of time afforded to channel estimation is presented. This second duration describes the time allotment for the purposes of channel parameter estimation; this last column arises from the following considerations.

In low-speed operation (*i.e.,* Barker encoded data), robust detection over a channel with multipath distortion is independent of a receiver estimate of the exact nature of the inter-symbol interference (ISI) distortion. The usual method of Barker code detection is to pass the received signal to a Barker correlator that is sampled at the 1 MHz code (symbol) rate. The operation of sub-sampling the Barker-correlator at 1/11 the chip rate means that multipath distortion caused by delays much smaller than the 1µs sampling period have little effect on the correlation output at the sampling times. This means that without any estimate of the exact delay, gain or phase of the multipath components, a reliable detection of the data is possible in the presence of significant multipath ISI.

In the high-speed modes of operation, both the CCK & PBCC, the effectiveness of the transmission detection over a channel with multipath distortion is **strongly dependent** on a reliable receiver estimate of the exact nature of the ISI distortion. This is why the intelligent design of the short preamble must seriously study the tradeoff between overhead and the ability to reliably estimate the channel ISI before switching to the high-rate mode. In all cases of Table 1, except the proposed, [1], CCK Header (row 4), the channel estimate can incorporate the Header transmission in the estimation procedure before switch to the high-speed coding that requires the effective ISI estimates.

Figure 3 shows the overhead, as a percent of the transmission, for both the 96µs and 80.7µs preambles with 2, 5.5 and 11 Mbps data transmission. As one can see, for the shorter preambles, the overhead for a 14-byte packet at 2Mbps requires ~60-~64% overhead while at 11Mbps, the overhead is ~90%. To achieve less than 10% overhead requires >200-byte, >600-byte and >1000-byte packet (respectively). In Figure 4, both the 80.7 µs and 80 µs preambles are compared; in this case the overhead is essentially equal.

[1] Rate 1/11 Barker with DBPSK (1 Mbps)
[2] Rate 1/11 Barker with DQPSK (2 Mbps)
[3] Rate 1/2 CCK with DQPSK (5.5 Mbps)

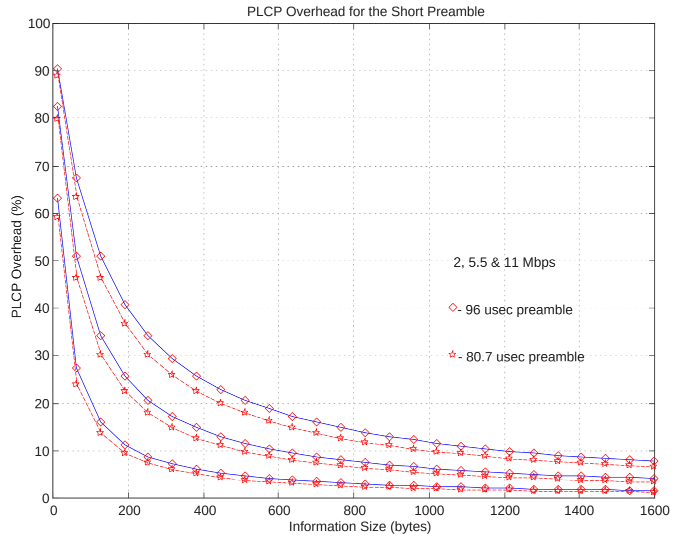

Figure 3: PLCP Overhead for a Short Preamble

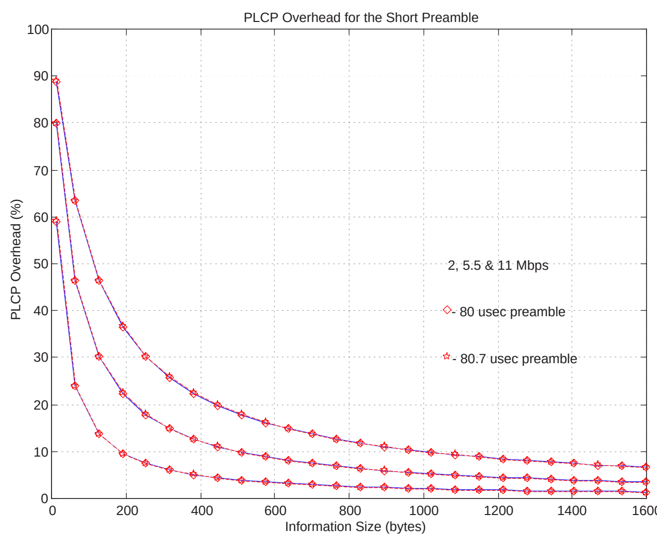

Figure 4: PLCP Overhead for another Short Preamble

In Figure 5, the throughput of the ideal system, with acknowledgement packets, is displayed. In this case three preamble lengths, 192 μs, 96 μs and 80 μs are shown using the 2Mbps, 5.5Mbps and 11Mbps data transmission speed. As one can clearly see, the benefits of the shorter preamble can have a valuable positive effect on the throughput. In comparing only the 96 μs and 80 μs preambles, one can see a less dramatic effect. In deciding the final length that is to be fixed by the 802.11 standard, one should account for the effect of other counter-balancing factors, such as the reliability of the channels parameter estimates as a function of preamble length.

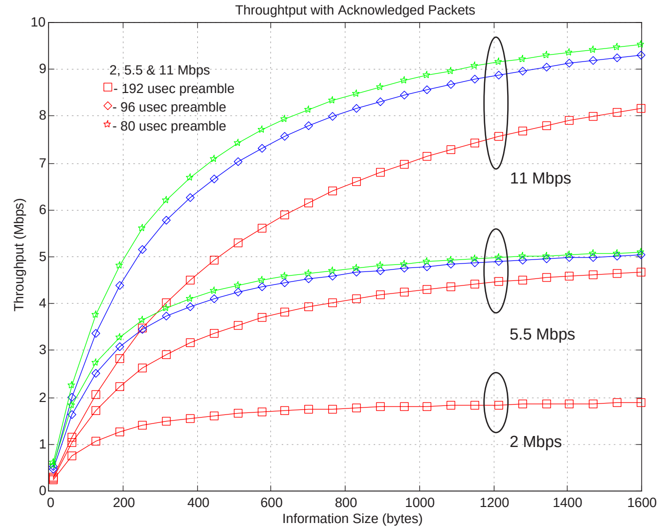

Figure 5: PLCP Throughput with the Long and Short Preambles

In Figure 6, a plot of the bit error rate (BER) of the various codes and modulations, as a function of the signal to noise ratio (SNR), are presented. In this case the SNR is measured in terms of actual channel signal to noise ratio (Es/No). The graph shows why it is unacceptable to combine a CCK Header when using the PBCC encoder. The reason follows from the simple fact that in order to effectively achieve the networking requirement of the PLCP overhead**, it is crucial the decoded Header information must be as reliable as the data portion of the packet**. If anything, in order to effectively perform the "clear channel assessment" (CCA) of the 802.11 MAC, one would like the Header to be *more robust* than the data. In order to fully benefit from the enhanced performance of the PBCC FEC, a CCK-encoded header is not sufficient. This follows from the fact that it is intended that the Header be correctly recovered by *every client* on the network while the data portion need only be error free at the output of the *intended receiver*.

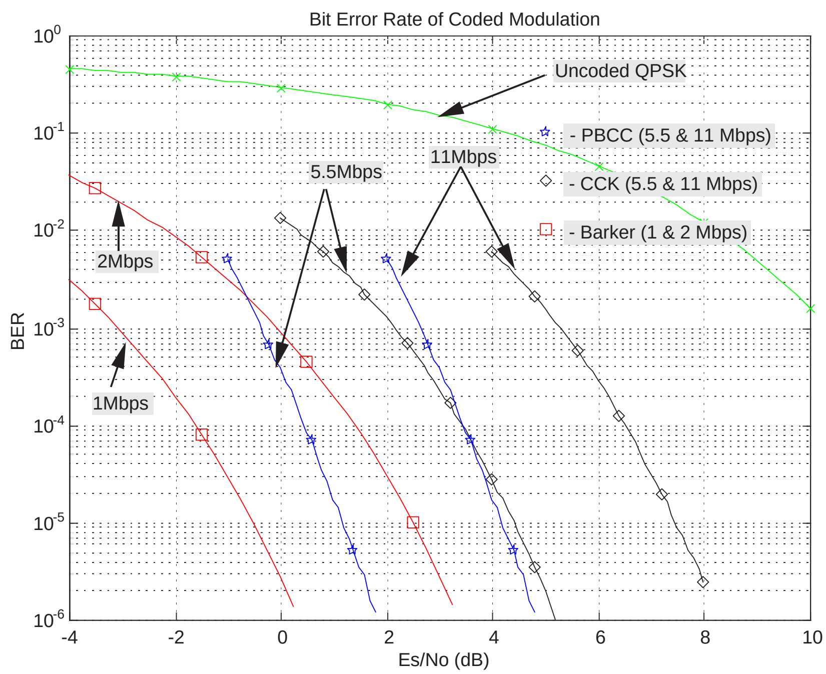

Figure 6: Bit Error Rate of Coded Modulation in AWGN

In Figure 6, it is clear that the reliability of the 5.5 Mbps CCK/DQPSK code is insufficient for this purpose. In the long preamble mode (1 Mbps Barker) the reliability of the PLCP header, and therefore the CCA effectiveness is the highest. The goal of the short preamble should be to retain, or compromise only modestly, the PLCP header reliability relative to existing, deployed equipment. The proposed 5.5 Mbps CCK-encoded PLCP header has >2 dB worse Es/No performance compared to the proposed 2 Mbps Barker-encoded PLCP header. The performance degradation of the CCK-encoded PLCP header results in less effective CCA; ultimately this dominate the reliability of the network and will lower the network robustness and throughput.

3 Specific Proposals for the High-performance Preamble

In all cases, in order to achieve interoperability in a high-speed only network, all receivers must detect the entire preamble (including header) in order to maintain CCA. In addition, the reliability of the Header information must be on par with the reliability of the data portion of the transmission. Based on these ideas, the following three choices follow:

1. 80 μs Preamble, Universal
    - A 40-bit SYNC with 1Mbps Barker/DBPSK
    - A unique 16-bit SFD with 1Mbps Barker/DBPSK
    - A 48-bit Header with 2Mbps Barker/DQPSK

2. 96 μs Preamble, Universal
    - A 56-bit SYNC with 1Mbps Barker/DBPSK
    - A unique 16-bit SFD with 1Mbps Barker/DBPSK
    - A 48-bit Header with 2Mbps Barker/DQPSK

3. 80.7 μs +80 μs Preamble, Dual
    - A 56-bit “CCK” SYNC with 1Mbps Barker/DBPSK
    - A 40-bit “PBCC” SYNC with 1Mbps Barker/DBPSK
    - A “CCK” 16-bit SFD with 1Mbps Barker/DBPSK
    - A “PBCC” 16-bit SFD with 1Mbps Barker/DBPSK
    - A 48-bit Header with 5.5Mbps CCK/DQPSK (CCK SFD)
    - A 48-bit Header with 2Mbps Barker/DQPSK (PBCC SFD)

It is our view that option 1 or 2 (or some similar arrangement) are most practical and we urge the committee to work in this general direction.

4 References:

[1] Mark Webster and Carl Andren, “The CCK 11 MBps Modulation for IEEE 802.11 2.4 GHz WLANs,” IEEE 802.11-98/315, Harris Semiconductor, September 14, 1998.