Title: BER vs. PER for DS Wireless LAN Performance Measure

Date: July 7, 1995

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Abstract

The DS PHY, FH PHY and IR PHY groups have defined performance parameters in terms of Bit Error Rate (BER) and/or Packet Error Rate (PER) in the 802.11 draft standard. There is a bit of concern by the entire 802.11 body on what to specify at the PHY level and what to specify for the overall MAC-PHY network when it comes to compliance testing. This paper presents an overview of the importance specifying both BER and PER for Differential Phase Shift Keying (DPSK) modulation and how one relates to the other for testing an 802.11 DS PHY layer modem. The paper concludes that both PER and BER are required. The issues discussed in this paper are not unique to the DS PHY but have attributes that maybe common to other PHY types as well.

Introduction

Over the past year a number of papers were presented defining packet length, PER performance, BER performance and the need for an exposed MAC-PHY interface as a means for measuring these parameters. One paper which comes to mind, was the submission by Jan Boer (IEEE P802.11-94/117) titled "Packetlength and Performance for the DS PHY". This paper reviewed in detail the importance of PER in packetized network. What seems to be unclear is BER and what role it plays as a measurement tool in a packetized network.

Definitions

BER measures the quality of a channel, which measures the number of erroneous bits received over a finite period of time. For example, In the case of the DS PHY, BER is specified in section 11.4.8.3 Receiver Adjacent Channel Rejection with a BER = 10-5. BER is calculated as follows:

$$BER = B_e/RT_m$$

Where:

R = channel speed in bits per second
B_e = number of bits in error
T_m = measurement period in seconds

Actual bit sequences for measurement are important to BER. Random digital data is generated by pseudorandom bit sequences. These sequences are repeatable in length taking on the function 2^n-1 bits, generating all but one possible word combination of bit length n. The most common sequences available with of-the-self test equipment are 512 and 2047 as defined by the CCITT, representing n=9 and n=11 respectively.

PER is measurement ratio of the number of packets received that contain at least one erroneous bit to the total packets received. PER is calculated by dividing the number of packets received in error by the number of packets transmitted. PER is also commonly called Frame Error Rate (FER) or Block Error Rate (BLER). In any case, PER is a very effective calculation for determining the overall MAC-PHY throughput in a channel for a given network. BER on the otherhand, is important to the DS PHY, for determining the Antenna-To-Bits(TM) performance of the modem.

Errors and Detection

Single bit errors in the transmitted packet, are generated from multiple sources, both internally and externally. These include clock oscillator jitter, harmonic distortion, gain hits, carrier signal dropouts, multipath and fading just to name a few. These error sources generate paired symbol bit errors for DPSK. Because the phase and data bits are determined by comparing the present symbol against the previous symbol. In any case, for every single received bit in error will cause 3 bit errors in the descrambler. The data scrambler/descrambler in section 11.2.4 is a feedforward shift register configured with the polynomial $Gx= 1 + x^{-4} + x^{-7}$. As each bit in error propagates through the shift register, an error is generated for each modulo 2 multiplication as defined by the x^{-n} taps. The Signal, Service and Length fields of the PLCP header are protected and checked for such errors. Any bit errors in these fields will be detected with the CRC-CCITT polynomial $Gx= x^{16} + x^{12} + x^5 + 1$ as defined in section 11.2.3.6. The CRC will detect 99% of the burst errors for 16 bits in length. Therefore, for any bit error in the PLCP header will constitute a packet error and represent a lossed packet at the PHY level.

General Overview

It appears that for the purpose of compliance testing of the DS PHY both BER and PER based measurements need to be performed. Both types of testing are important in the characterization of the 802.11 DS PHY. BER is used because it is more readily instrumented. BER measurements are appropriate for obtaining basic data on the demodulation processing and in verifying specifications that are targeting the RF and IF levels of the design.
The requirements that can potentially be tested more efficiently using continuous data (BER measurements) include: modulation accuracy, clock accuracy, carrier suppression, and receiver sensitivity.

One argument against BER testing is that it requires the designer to expose a port for continuous data and to make available a mode that allows for continuous data. It is believed though that every PHY manufacturer will have to expose such interfaces for the testing of their devices.
BER measurements can not test alone the requirements of the standard. PER measurements, are more meaningful from an overall network performance and compliance testing. In addition there are some facets that the BER tests can potentially miss.

Generally, when BER tests are run, the preamble is used to obtain initial signal acquisition followed by the data stream for as long as necessary to make the measurements. This approach can miss some important aspects of packet networking and modem operation. One of the concerns is that the acquisition process in not tested in a thorough way by using this approach. The initial acquisition or PN acquisition design parameters of a typical DS PHY receiver are separate from the parameters that govern data demodulation and data tracking. Since during BER tests, the acquisition sequence will be transmitted once followed by a continuous stream of many data bits, any errors on the preamble will be absorbed by the overall BER measurements of the data stream. If performed this way the BER measurements can be very effective in verifying many RF, IF and demodulation specifications but they can hide any imperfections of the acquisition performance that can impact the packet error rate and consequently the overall network performance.

The preliminary 802.11 specification drafts imply that any error in the PLCP detected by the CRC check will result in a missed message and the MAC should reset and resume acquisition processing. If the error is in the data, then the packet is discarded after demodulation and CRC checking. Thus acquisition errors are just as detrimental as data errors to packet success. One could argue that, since the preamble is relatively long and is always BPSK, the acquisition probability should be near unity. However, there are some design areas that if not carefully implemented they can reverse the favorable probabilities in detection and impact packet error rates to a great extend.
It is recommended that there are testing provisions to evaluate these acquisition design areas. There are two basic reasons of concern that a PER test must be used to mitigate compliance risk.

A. Settling Transients

DS receiver designs utilize mostly first order or second order tracking loops in the demodulation process for symbol timing or carrier tracking. With these loops there is a settling time associated. The settling transients will result to a reduced BER during that portion of the message. These settling transients occur in the early portion of the packet and therefore they effect the acquisition performance. The performance impact to acquisition will not be seen in a standard BER test. The settling time of the loops is an implementation issue and has not been directly specified in the present drafts. The effect of these loop designs though needs to be evaluated as a function of PER. A BER test can potentially fail to detect the settling transient effects which can significantly degrade packet error and consequently network performance.

B.Two Antenna Design Option

With the two antenna diversity option used for multipath mitigation, the acquisition probability of the preamble can be reduced, dependent on the design implementation. In a sequential search approach for example the modem must scan the two antennas and dwell on each long enough to get a high probability of detection. This can reduce the number of preamble symbols available to acquire to half for each of the antennas. The problems associated with settling transients, as described above, are now amplified because there are only half the preamble symbols per antenna to achieve the acquisition requirements. The designs with antenna diversity need to be evaluated for their probability of acquisition and the preferred testing approach should be through PER.

One consideration is how to measure packet error rates. The system does not inherently count packet failures and you have to know one was sent in order to determine if you should count one missed. Generally, a closed loop test in the lab should have no trouble with this. One measure suggested for open loop tests is to count packets for which no ACK is received. This presumes that there will be no ACK reception failures. We could probably insure this by making the transmit power of the ACK higher than that of the packet.

There are many reasons in a fielded system why a packet might be lost. These are collisions, interference, and multipath fades. Our main concern in testing is not for these factors but for those problems inherent in the physical layer implementations. **Thus, we recommend that manufacturers use both BER and PER tests to characterize the PHY.** To satisfy the need for system specifications, we recommend that only PER tests be used since these test all aspects of the phy layer and don't get into which test is more stringent for a given design.

References

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