IEEE 802.11
Wireless Access Method and Physical Specification

title: **Packetlength and Performance for the DS PHY**

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1. INTRODUCTION

In 802.11 discussions have been started on the need of fragmentation of packets in the MAC. The assumption is that the PHY can not deliver packets at an acceptable Packet Error Rate (PER) without fragmentation such that ,as stated in the PAR, ' The MAC Service Data Unit (MSDU) loss rate shall be less than 4*10e-5 for an MSDU length of 512 octets'.
This submission will give relations for Packet length, PER, coverage and channel distortion for a Direct Sequence system as defined in doc IEEE 802.11-93/232r2.

2. DISTANCE CALCULATIONS

The path loss model has significant influence on the distance calculations. The formula below (from Lee[1]) reflects the various path loss contributions (simplified; no walls or floors are taken into account):

[1] W.C.Y. Lee, Spectrum Efficiency in cellular, IEEE Transactions on Vehicular Technology, vol 38, no 2, May 1989, pp 69-75.

$$L = L_0 - 10n_1 \log_{10}\left[\frac{\lambda}{4\pi d_{ref}}\right] + 10n_2 \log_{10}\left[\frac{d}{d_{ref}}\right]$$

where

L_0 = antenna gain / loss (dipole -2 dB)

λ = wavelength

d_{ref} = reference distance transmitter

d = transmitter / receiver distance

n_1 = decay exponent below d_{ref}

n_2 = decay exponent above d_{ref}

The second term of the above formula gives the isotropic loss with respect to the reference distance of 1 meter. For 2.4 GHz this loss is 40dB. The third term is the exponential path loss term; we assumed n=2, corresponding with free space propagation for the first 10 meter, further n=3.5 is used (office area).

For the calculation of the maximum distance the power of the transmitter and the sensitivity level of the receiver is important. The calculations are done at a transmit power level of 1 Watt and 100 mW (FCC and ETSI maximum values). The receiver sensitivity level for the DSSS system is specified at -80dBm at a BER of 10^{-5} @Eb/No of 17 dB.

For a (flat) Raleigh fading environment (no delay spread) the fading margins to take into account are given by e.g. Jakes [2].
With 2 antenna diversity the fading margin (for a outage of 0.1%) is 15 dB. For a 1% outage a fading margin of 10 dB is sufficient. In the calculations we use 15dB because the PAR requires a channel availability of 99.9%.

This simple model gives the maximum distances for a BER of 10^{-5}:

Power level 1 Watt	130 meter for outage 0.1%	(190 meter for outage 1%)
Power level 100mW	67 meter for outage 0.1%	(93 meter for outage 1%)

3. PACKET ERROR RATE

The packet error rate (PER) is a function of the BER and the packetlength. The next table gives the PER at above calculated distances (BER 10^{-5}) for different packet length:

[2] W.C.Jakes, Jr., Microwave Mobile Communications, Wiley & Sons, 1974, p315, fig. 5.2-2

packet length (bytes)	PER
128	0.01
256	0.02
512	0.04
1024	0.08
2048	0.16

The PER at sensitivity level is about 1 every six packets for 2048 bytes.
When the distance between the transmitter and receiver gets smaller the SNR improves rapidly and so the BER. Roughly the BER improves a factor of ten at each 0.9dB SNR improvement.
The next figure gives the PER as function of distance for different packet lengths (128,512 and 2048 bytes)

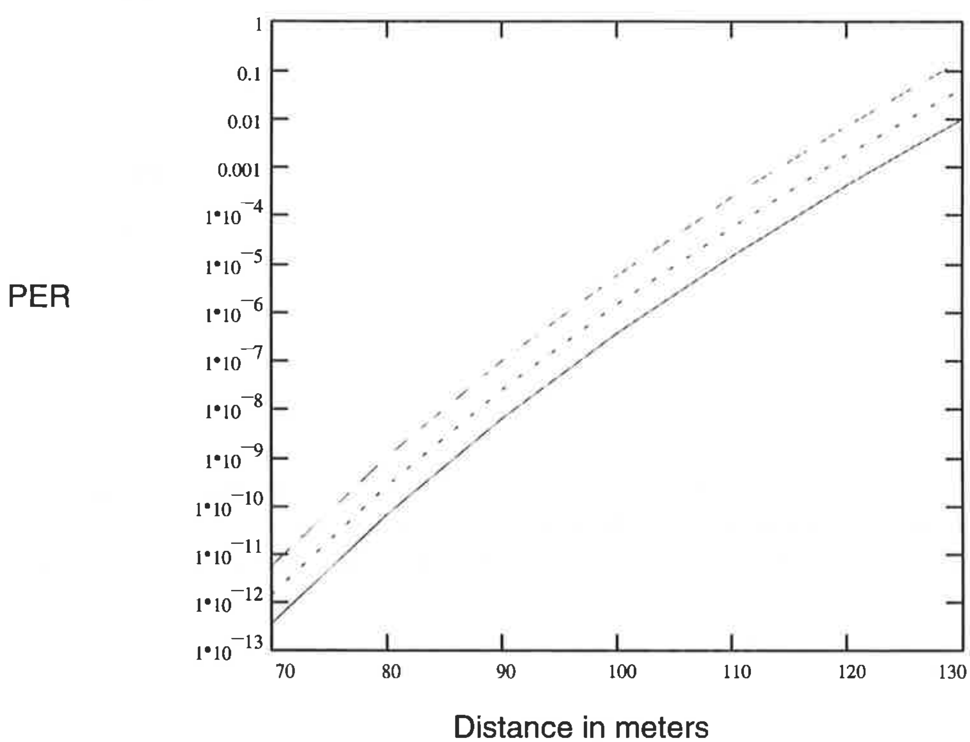


Figure 1 . Packet error rate as function of distance. Transmit power is 1 Watt. Packetlength 128 (dashed), 512 (dotted) and 2048 (solid) bytes.

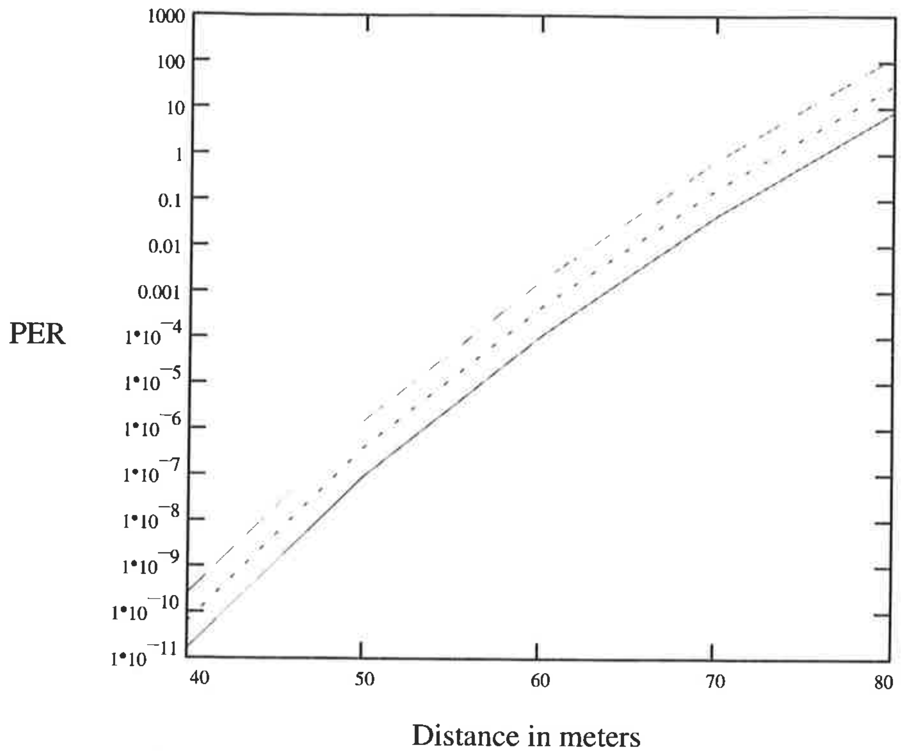


Figure 2 . Packet error rate as function of distance. Transmit power is 100 mW. Packetlength 128 (dashed), 512 (dotted) and 2048 (solid) bytes.

4. EFFECTS OF DELAYSPREAD

A Direct Sequence Spread Spectrum system is relatively robust against delay spread. To assess the effect of the channel on PER and distance we use a simplified approach.

The channel degradation is composed from the convolution of the channel impulse response and the spike waveform of the 11-bit Barker sequence.

The spike waveform of the Barker sequence is +1 or -1 at the peaks and +1/11 or -1/11 in between.

The channel response has the duration of 11 samples each complex valued. Such a response can be simulated using gaussian based amplitude with the exponential shape and random phase. For simplicity we use here the 'average' channel with a power profile with an exponential shape. The calculations are done for a delayspread of 181ns. When we use 11 samples per symbol (11 MHz, sampletime 90 ns) the profile looks like figure 3:

$$PowerProfile_t := e^{-\left(\frac{t}{\tau}\right)} \qquad \tau := 2$$

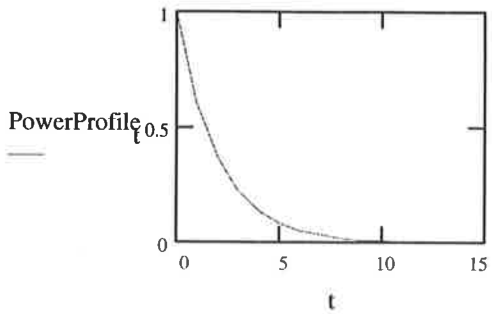


Figure 3: Channel power profile for delayspread of 181 ns (2/11MHz)

The power in the peak after the correlator will be worst case:

$$Peakpower = Powerprofile_0 - \frac{1}{11}\sum_{i=1}^{10} Powerprofile_i$$

(assuming that the impulse response is died out after the 11th sample.)

The second term is the worst case interference of the echoes on the peak.
The sum of the power in the other samples (the echoes) after correlation is:

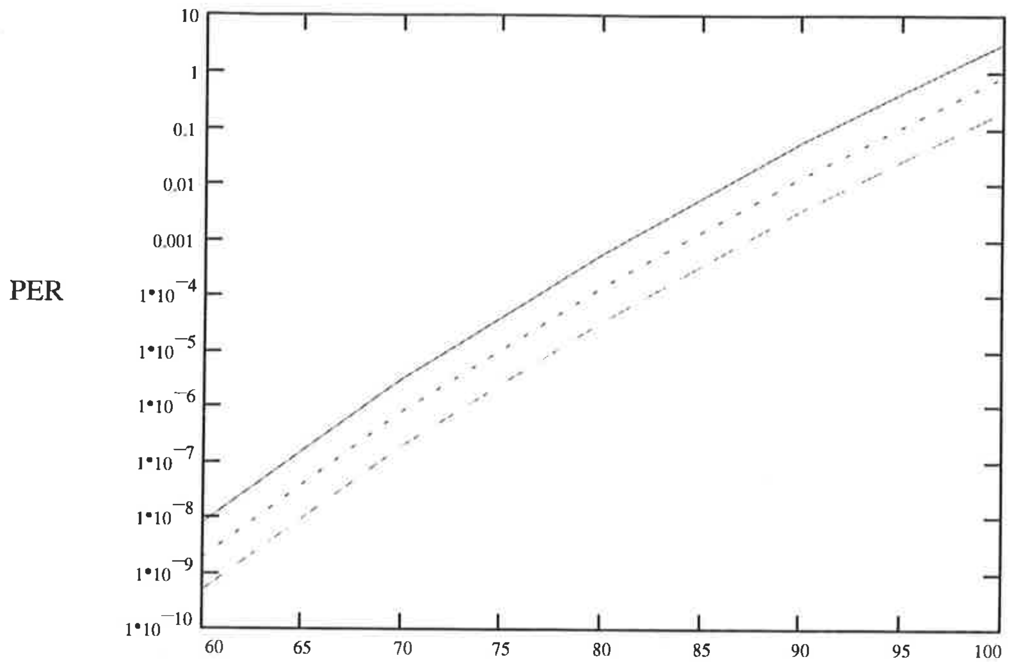
$$Echopower = \sum_{i=1}^{10} Powerprofile_i$$

With a 'choose largest' approach in the receiver, the loss of power in the peak due to the channel can be assessed as:

$$Loss = 10.\log\left(\frac{Echopower}{Peakpower}\right) \text{ dB}$$

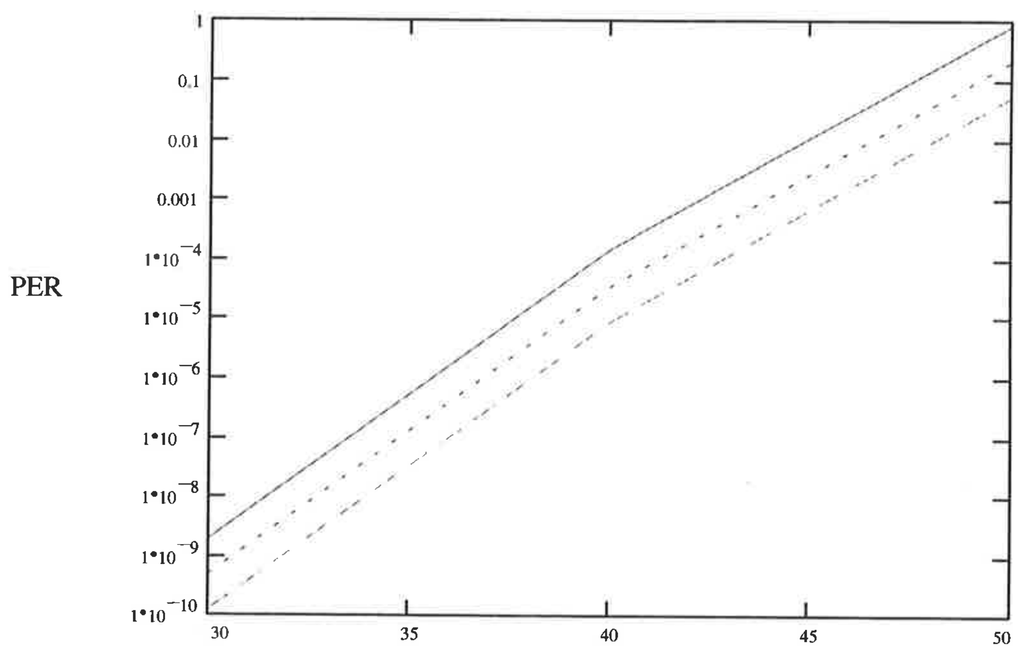
Taking this loss into account again the figures are composed for the PER against distance for an output power of 1 Watt and 100 mW.

In both figure 4 (1 Watt) and 5 (100mW) (next page) it can be seen that the distance for a certain PER will increase only 5 meters when the packet size is reduced from 2048 to 128 bytes. Even in a heavily distorted environment with delay spread up to 200ns distances are from 40 (100mW) to 80 (1 Watt) meters for a PER around 10^{-5}.



Distance in meters

Figure 4 . Packet error rate as function of distance at dealyspread of 181ns. Transmit power is 1 Watt. Packetlength 128 (dashed), 512 (dotted) and 2048 (solid) bytes.



Distance in meters

Figure 5 . Packet error rate as function of distance at delayspread of 181ns. Transmit power is 100mW. Packetlength 128 (dashed), 512 (dotted) and 2048 (solid) bytes.

5. PACKETLENGTH AND OVERHEAD

The transmission of each packet is associated with overhead. In the 802.11 DS system this overhead consists at least out of:

1. training (192µs)
2. training + Ack (256µs?)
3. IFS
4. optional RTS/CTS

If we assume a total of 512 µs this means a overhead per packet of 128 bytes for the 2 Mb/s system (2 bits per µs).
For a packetlength of 512 bytes this means a overhead of 25 %, while this is for 2048 bytes 6.25%. The question is if the increase in overhead will pay back when smaller packets are transmitted.
The answer is negative. Refer e.g. to figure 5. At 45 meters the PER for 512 byte packets is 0.001, for 2048 byte packets 0.01: this is a factor 10 difference. Retransmission overhead is then for 512 byte packets 0.1%, while this is for 2048 bytes packets 1%. The retransmission overhead in both cases is much less then the overhead associated with each packet.

6. CONCLUSIONS AND DISCUSSION

In this submission we described the relation between Packet length, Packet Error Rates, coverage and channel distortion. The calculations made give no reason to set a maximum packet length to less than 2048 bytes.
The assumptions made for these calculations may look to much simplified, we do not expect that more sophisticated calculations or simulations will change the conclusion.
In the field there are thousands of similar DS systems running without problems. No fragmentation is applied while these systems are handling Ethernet like packets.
The conclusion is that fragmentation from a DS standpoint is not necessary. If 802.11 decides that a maximum framelength is to be defined than this maximum framelength should be PHY dependent. For the DS PHY this number is higher than 2048 bytes.