

PERFORMANCE OF IEEE 802.11B WIRELESS LOCAL AREA NETWORK

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ABSTRACT

The objective of this paper is to investigate the performance of IEEE 802.11b Wireless Local Area Network (WLAN), which works at the unlicensed Industrial, Scientific and Medical (ISM) band. The Bit Error Rate (BER) performance of the different transmission techniques of WLAN have been compared under single path and multipath propagation conditions. The effect of interference from another co-channel WLAN has also been investigated.

1. INTRODUCTION

Wireless Local Area Networks [1] (WLANs) have been one of the great communications technology success stories of the past few years. WLAN operates in the 2.4000-2.4835 GHz unlicensed Industrial, Scientific and Medical (ISM) band [1]. The first WLAN standard, IEEE 802.11 was published in 1997. It provides data rates of 1 and 2 Mbps and supports Direct Sequence Spread Spectrum (DSSS) [2], Frequency Hopping Spread Spectrum (FHSS) [2] and Diffused Infrared (DFIR) [1] physical (PHY) layers. New PHY layer supporting 5.5 and 11 Mbps using Complementary Code Keying (CCK) [1] has been amended in 1999. This revision is known as IEEE 802.11b WLAN standard [3] and is the most popular WLAN standard. In this paper we compare the performance of the dominant transmission techniques of IEEE 802.11b namely DSSS and CCK.

IEEE 802.11 standard defines two layers of the entire protocol stack: Medium Access Control (MAC) and the PHY layer. The MAC layer is responsible for ensuring fair, protected, reliable and collision free network operation. The PHY layer lies just below the MAC layer and serves as an interface to the physical medium and deals with the transmission and reception of data over the air. The simulations carried out in this paper implements

most of the features of the physical layer. Here is how the rest of the paper is organized. Section 2 provides a brief description of the PHY layer of the IEEE 802.11b standard. Section 3 presents the simulation environment, results and discussion on the results. Section 4 concludes this paper.

2. IEEE 802.11B WLAN PHYSICAL LAYER

IEEE 802.11b specifies four different PHY layers [1] namely: DSSS, FHSS, DFIR, High Rate DSSS (HR/DSSS). In DSSS, the data is multiplied with a Spreading Sequence (PN Sequence), which *spreads* the signal over a wider bandwidth. The bit rate for this technique is 1 or 2Mbps [1]. In FHSS technique, the transmitter shifts the center frequency of the transmitted signal according to a pseudorandom pattern that is known only to the transmitter and the receiver. In IR, the data is sent with infrared light and requires line of sight [1]. This technique has never become popular. HR/DSSS occupies almost the same spectrum as DSSS and it uses CCK as the modulation technique. The data rate here is higher than the original DSSS, i.e. 5.5 to 11 Mbps instead of 1 to 2 Mbps. A description of the transmission techniques investigated in this paper is given next.

2.1. DSSS Transmission

DSSS is performed by taking a binary data stream and modulating it with a chipping sequence. In 802.11 this is an 11 bit sequence known as the Barker code [1]. Here each group of 11 chips encodes one bit of data. Differential Binary Phase Shift Keying (DBPSK) [4] is used (one phase shift for each bit) for 1 Mbps DSSS transmission. In order to accomplish 2 Mbps transmission, Differential Quaternary Phase Shift Keying (DQPSK) [4] modulation is used. DQPSK uses four rotations (0, 90, 180 and 270 degrees) to encode 2 bits of information in the same space as DBPSK encodes 1. A simple despreading and correlation [4] can perform the task of demodulation for both the cases.

2.2 HR/DSSS Transmission

HR/DSSS uses Complementary Code Keying [2] where the symbol duration is exactly 8 complex chips long. The following formula is used to derive the CCK code words in order to spread both 5.5 and 11 Mbps:

$$C = \left\{ e^{j(\varphi_1 + \varphi_2 + \varphi_3 + \varphi_4)}, e^{j(\varphi_1 + \varphi_3 + \varphi_4)}, e^{j(\varphi_1 + \varphi_2 + \varphi_4)}, -e^{j(\varphi_1 + \varphi_4)}, e^{j(\varphi_1 + \varphi_2 + \varphi_3)}, e^{j(\varphi_1 + \varphi_3)}, -e^{j(\varphi_1 + \varphi_2)}, e^{j(\varphi_1)} \right\} \quad (1)$$

where C is the CCK codeword. The terms $\varphi_1, \varphi_2, \varphi_3, \varphi_4$ are chosen differently for 5.5 and 11 Mbps transmission.

In the 802.11 wireless LAN 5.5 Mbps CCK mode, the incoming data is grouped into 4 bits nibbles where 2 of those bits select the spreading function out of the set of 4 while the remaining 2 bits DQPSK modulate the entire symbol [5]. So out of the 4 bits symbol, the first two bits (d_0, d_1) encode φ_1 based on DQPSK modulation. The phase change φ_1 is relative to the preceding phase φ_1 and even and odd symbols are rotated π radians from each other. The last two bits (d_2, d_3) encode φ_2, φ_3 and φ_4 according to [5]:

$$\varphi_2 = d_2\pi + \pi/2; \varphi_3 = 0; \varphi_4 = d_3\pi \quad (2)$$

In 802.11 WLAN 11Mbps CCK mode, the input data is grouped into 8 bits symbols. Here the first two bits (d_0, d_1) encode φ_1 based on DQPSK modulation. It is the same as for CCK for 5.5 Mbps data rate. The second pair of bits (d_2, d_3) encodes φ_2 , the third pair of bits (d_4, d_5) encodes φ_3 and the fourth pair of bits (d_6, d_7) encodes φ_4 all based on QPSK as shown in Table 1. In 11 Mbps CCK mode, the 8 input data bits are grouped so that 6 bits select one of 64 complex vectors of 8-chip length for the symbol and the other 2 bits DQPSK modulate the entire symbol. The chipping rate however is maintained at 11 Mcps for both modes.

At the receiver, each eight received complex wave forms from the DQPSK demodulator are grouped in a block and sent to the decoder to find the closest 4/8 bit symbol (depending on whether the rate is 5.5 or 11 Mbps respectively) associated with the demodulated 8 four-phase signals.

3. SIMULATION RESULTS AND ANALYSIS

This section shows the results and analysis for the different transmission techniques of WLAN simulated under single path as well as multipath propagating condition. The noise is assumed to be Additive White Gaussian Noise (AWGN) [4]. The effect of interference from another co-channel

WLAN is also simulated. BER versus Signal to Noise Ratio (SNR) curves are used as the performance metric.

Table 1 [6]: QPSK encoding table for 11 Mbps

d_i Bit Pattern (d_0, d_1)	Phase change Even Symbols	Phase change Odd Symbols
00	0	π
01	$\pi/2$	$3\pi/2$ ($-\pi/2$)
11	π	0
10	$3\pi/2$ ($-\pi/2$)	$\pi/2$

3.1 BER Performance for AWGN

Figure 1 shows the performance of DSSS and CCK transmission techniques in a single path channel where the only impairment is AWGN. It is evident that at low SNR, DSSS provides better performance than CCK. But after about 2.5dB the performance of CCK technique becomes better. This is in agreement with theoretical analysis [4]. The performance of DSSS for both 1 Mbps and 2 Mbps is identical since the BER of DBPSK and DQPSK is the same [4]. Similarly the performance of CCK for 5.5 Mbps and 11 Mbps is the same. As a result we are going to show the results for 2 Mbps and 11 Mbps data rate from now on.

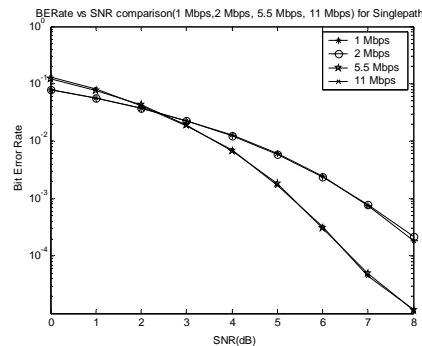


Fig.1 Comparison between 1 Mbps & 2Mbps DSSS and 5.5 Mbps & 11 Mbps CCK for Single Path

3.2 BER at Multipath Channel

Multipath distortion is due to the fact that while going from one wireless device to another, a signal can take several routes. Multiple copies of the transmitted signal thus reach the receiver at different times and at different strengths causing distortion.

In order to simulate the effects of multipath propagation three different channels have been considered. The characteristics of Channel 1 were adopted from IMT 2000 indoor channel model [6]. Channel 2 characteristic represents an exponentially decreasing channel impulse response while the characteristics of Channel 3 are that of a *benign*

channel with very small multipath components. Table 2 shows the power delay profile [2] of the three channels:

Table 2: Characteristics of the Multipath Channels

Channel Coefficients (α)			Relative delay (chip)
Chan. 1	Chan. 2	Chan. 3	
1	1	1	0
0.6	0.3679	0.1	1
0.0158	0.1353	0.01	2
0.0031	0.0498	0.001	3

Figures 2,3 and 4 show the BER vs SNR curves for channel 1, 2 and 3 respectively. The performance of 2 Mbps DSSS is significantly (about 3.5 – 4 dB) better compared to 11 Mbps CCK for channel 1. The better performance of 2 Mbps DSSS compared to CCK can be attributed to its processing gain. The processing gain causes the delayed versions of the transmitted PN signal to have poor correlation with the original PN sequence. As the multipath induces at least one chip of delay in the simulation, the multipath signals arrive at the receiver such that they are shifted in time by at least one chip from the first signal. Thus appear as another uncorrelated user that is ignored by the receiver. Consequently multipath contributions appear insignificant to the desired received signal for DSSS techniques.

The performance of 2 Mbps DSSS is better than 11 Mbps CCK for channel 2 also. However, since this channel is comparatively *better* than channel 1 because of smaller multipath components, the difference in performance is moderate. Since channel 3 very closely resembles a single path AWGN channel, the performances for both the modulation schemes are similar to those in a single path environment.

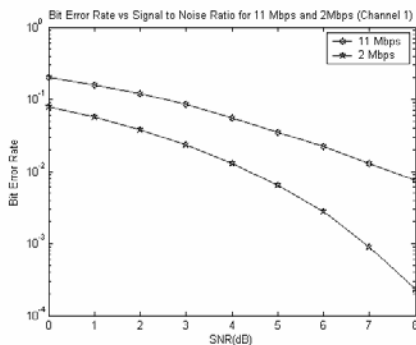


Fig. 2 Comparison between 2Mbps DSSS and 11 Mbps CCK for multipath channel 1

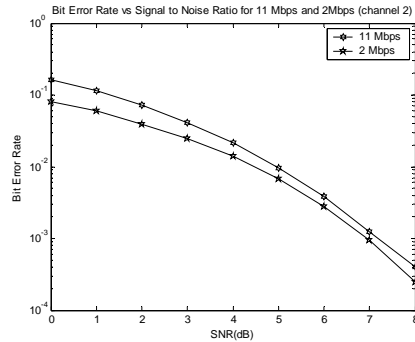


Fig. 3 Comparison between 2Mbps DSSS and 11 Mbps CCK for multipath channel 2

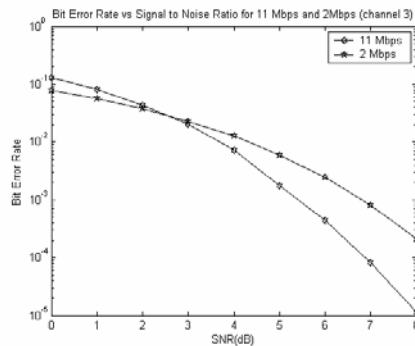


Fig. 4 Comparison between 2Mbps DSSS and 11 Mbps CCK for multipath channel 3

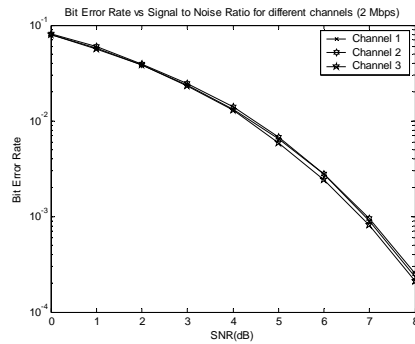


Fig. 5 Performance of 2 Mbps DSSS under three different multipath channels

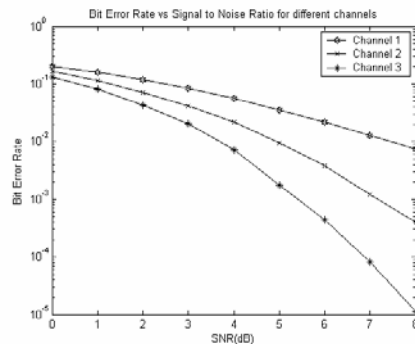


Fig. 6: Performance of 11 Mbps CCK under three different multipath channels

The performance of DSSS transmission technique remains the same for all three channels by virtue of its processing gain. However the performance of CCK modulation deteriorates drastically as the multipath components become stronger, i.e. the channel becomes more and more frequency selective [2]. These facts are evident from Figures 5 and 6. Consequently if the WLAN system was employed outdoors where the channel is likely to be frequency selective, it will be difficult to attain data rates higher than 2 Mbps.

3.1 Co-Channel Interference

Co-channel interference [2], is one of the major reasons of performance degradation in a wireless network. In this section we have investigated the performance degradation resulting from a co-channel WLAN system.

Figures 7 and 8 show the performance of 2 Mbps DSSS and 11 Mbps CCK transmission techniques at the presence of co-channel interference. We assume that the channel is single path with only AWGN impairment. The performance curves are for 0, 5 and 10 dB Signal to Interference Ratio (SIR). A BER curve for the case when no co-channel interference is present is also drawn as the baseline. From the figures it can be seen that DSSS is resistant to interference from other wireless LAN in comparison to CCK technique. In DSSS, most of the original interference energy is eliminated during spreading and minimally affects the desired receiver signal. The greater the processing gain of the system the greater will be its ability to suppress inband interference. As a result the performance of the DSSS does not deteriorate at the presence of co-channel interference. Since CCK does not have this property, as interference increases its performance decreases significantly even though CCK provides higher data rate.

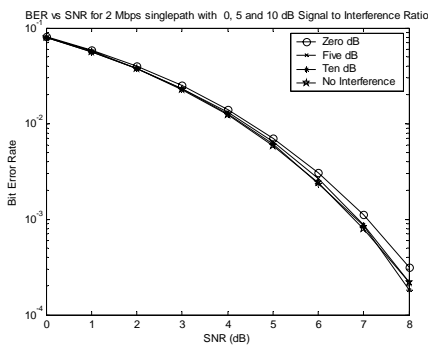


Fig. 7 Comparison for 2 Mbps DSSS under single path channel with 0, 5 and 10dB SIR

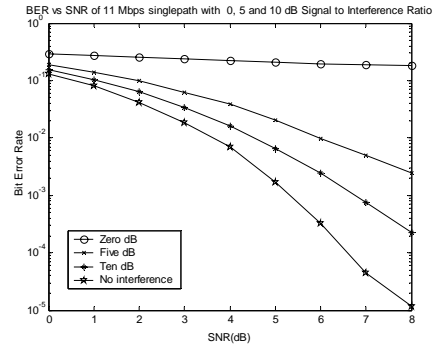


Fig. 8 Comparison for 11 Mbps CCK under single path channel with 0, 5 and 10dB SIR

4. CONCLUSION

We can conclude from the simulation results and analysis that CCK, which provides higher data rate, performs better in single path AWGN channel and under weak multipath channel. Its performance deteriorates, as the multipath becomes stronger. On the other hand DSSS, which provides lower data rate does not perform well in single path environment. However it performs consistently well under different multipath environments i.e. performance of DSSS does not deteriorate as the multipath becomes stronger. Also, due to its processing gain co-channel interference does not degrade the performance of DSSS. However, in case of HR/DSSS i.e. CCK, the presence of another WLAN as an interferer causes significant degradation of its performance.

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