Wireless Standard (IEEE 802.11b) Simulation Project Proposal

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Course: ECE408 Wireless Communications
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1 Purpose

This project aims to demonstrate a wireless standard and implement its physical layer in MATLAB. The standard to be explored is IEEE 802.11b ("WiFi 1"), which was first introduced in 1999. The scope of this transmission standard implementation is within the physical layer, so aspects including security, authentication, encryption, handoffs are not to be considered to a considerable extent.

2 Description

The IEEE 802.11b standard has a maximum raw data rate of 11 Mbps over 3 channels within a 35m range (indoor) and 140m (outdoor), operating in the 2.4 GHz frequency band, which is one of the ISM bands also used for devices including microwave ovens, Bluetooth devices, baby monitors, cordless telephones, and some amateur radio equipment [2, 3].

In practice, however, the CSMA/CA protocol overhead prevents from reaching its maximum throughput, achieving about 5.9 Mbps using TCP and 7.1 Mbps using UDP. This 802.11b standard is a direct extension of the direct-sequence spread spectrum (DSSS) modulation scheme defined in the original standard. Along with high rate (HR-) DSSS, it also uses complementary code keying (CCK) as its modulation technique, with a specific set of length 8 complementary codes that was originally designed for OFDM but was also suitable for use in 802.11b because of its low autocorrelation properties. At lower data rates, it allows to scale the data rate to 1, 2, 5.5 and 11 Mbps by adaptive rate selection in order to decrease the rate of re-broadcasts that result from errors. Instead of using differential quadrature phase shift keying (DQPSK) at lower rates, CCK provides better performance under interference and multipath fading [6, 7].

802.11b is typically used in a point-to-multipoint configuration, wherein an access point communicates via an omnidirectional antenna with mobile clients within the range of the access point. Allowable bandwidth is shared across clients in discrete channels. A directional antenna focuses transmit and receive power into a smaller field which reduces interference and increases point-to-point range. In US, channels 1–11 (with center frequencies at 2.412 – 2.462 GHz and 5 MHz distance) are available, in which for 11 Mbps data rate channels 1, 6, and 11 (non-overlapping) give the maximum number of channels with minimum interference [4].

One unique characteristic of 802.11b is that different PHY layer parameters are set for different data rates.

Data Rate	Chipping Code Length	Modulation	Remark
1	11 (Barker seq.)	DBPSK	-
2	11 (Barker seq.)	DQPSK	-
5.5	8 (CCK)	DBPSK	first 2 bits DQPSK, next 2 bits CCK
11	8 (CCK)	DQPSK	first 2 bits DQPSK, next 6 bits QPSK

Table 1: 802.11b Modulations by Data Rates

3 Approach

The PHY layer specification for the 802.11b consists of transmitter and receiver components, each broken down into smaller blocks, such as scrambler, modulator and pulse shaping filter as reference in 'rfwireless-world' website (see Figures 2, 3) [1].

The document referenced for HR/DSSS PHY specifications is IEEE 802.11 Standards-2016 Release (Ch 16). Since the parameters like the preamble, modulation technique and symbol rates are all different for the supported four data rates (1, 2, 5.5, 11 Mbps), they would need to be adjusted accordingly, as follows:

- **1 Mbps**: DBPSK modulation, DSSS scheme, long preamble, 1 bit/symbol
- **2 Mbps**: DQPSK modulation, DSSS scheme, long/short preamble, 2 bits/symbol
- **5.5 Mbps**: CCK modulation, CCK scheme, long/short preamble, 4 bits/symbol, first 2bits DQPSK modulated and next 2bits CCK modulated)
- **11 Mbps**: CCK modulation, long/short preamble supported, 8 bits/symbol, first 2bits DQPSK and next 6 bits QPSK

Another optional mode that allows for data throughput at the higher rates (2, 5.5, and 11 Mb/s) is using a shorter PHY preamble ("HR/DSSS/short"), and this shorter mode can coexist with DSSS, HR/DSSS under limited circumstances, such as on different channels or with appropriate CCA mechanisms. The packet formats for long and short preamble types are described in Figure 1. The general packet structure consists of a preamble, a header and a signal block.

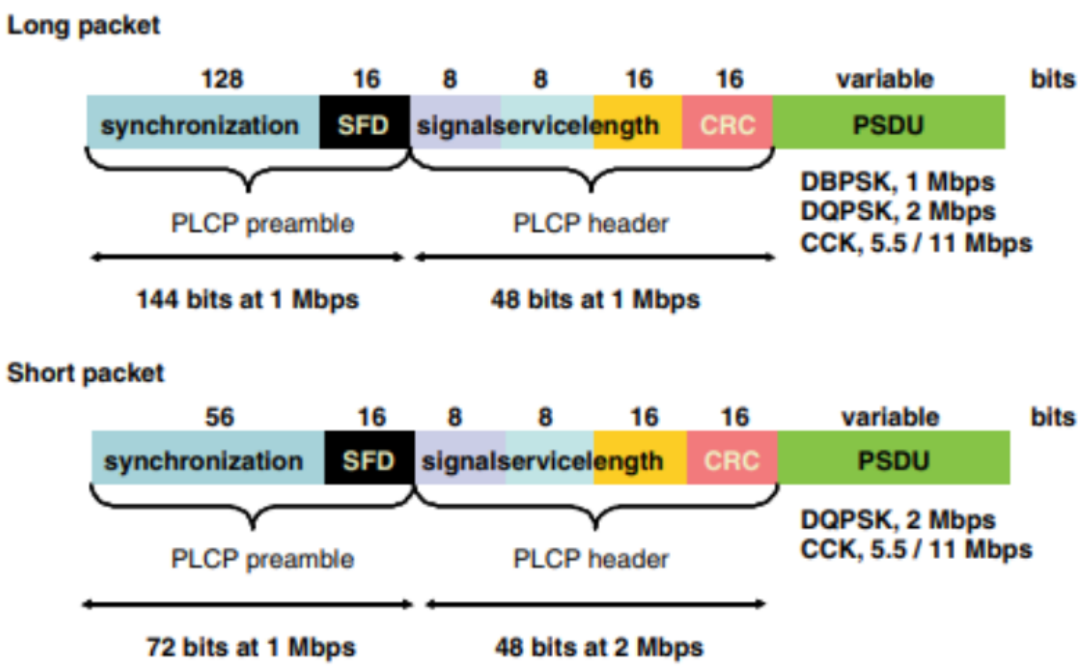

Figure 1: 802.11b DSSS PHY Packet Formats

A preamble contains synchronization block (sequence of pulses in a series of slots) and also specifies the start frame delimiter (SFD), which allows the receiver to find the beginning of the frame. This 2-byte SFD field is represented by the sequence 1111 0011 1010 0000 in the case of a long preamble, and its opposite 0000 1100 0101 1111 in the case of a short preamble, for example. Note that the smaller size (56-bit set to 0, as opposed to the IEEE 802.11 standard 128-bit set to 1) of the scrambled bits for a short preamble (only for 2, 5.5, 11 Mbps) reduces the overhead. The preamble must be transmitted at 1 Mbps with a DBPSK modulation for long packets, and at 2 Mbps with a DQPSK modulation technique to reduce the overhead time contribution. The signal block specifies the modulation scheme for the desired data rate – 0x0A for 1 Mbps with a DBPSK modulation, 0x14 for 2 Mbps with a

DQPSK modulation, 0x37 for 5.5 Mbps with a CCK4 modulation and 0x6E for 11 Mbps with a CCK8 modulation [5].

After resolving the packet protocol data unit (PDDU), the packet will be transmitted through a Tx as specified in Figure 2, an AWGN channel, and a Rx as specified in Figure 3. Although 802.11b may seem a bit old, this will enrich understanding of the modulation schemes widely used prior to OFDM as it was the first WiFi technology deployed (as called "WiFi 1").

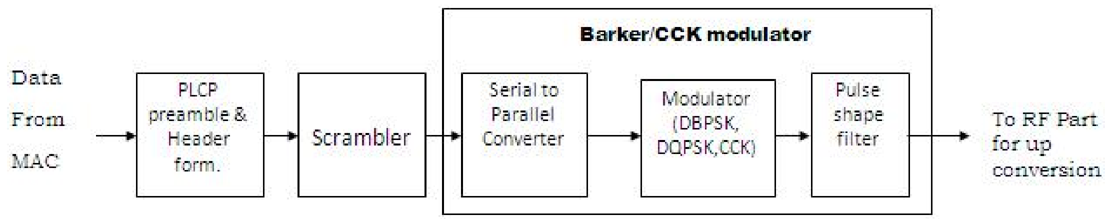

Figure 2: 802.11b Transmitter Block Schematic

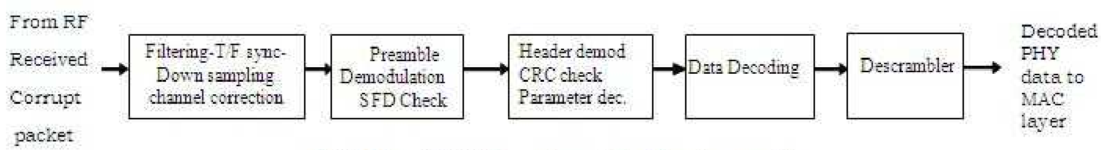

Figure 3: 802.11b Receiver Block Schematic

4 Deliverables

The outcomes of this simulation project include a published MATLAB format of well-commented code for the AWGN link, and relevant BER vs. SNR curves for different data rates as discussed above.

References

[1] *802.11b-1999*. URL: `https://www.rfwireless-world.com/Articles/802.11b-1999.html` (visited on 02/04/2020).

[2] *Difference between 11a,11b,11g,11n — 11a vs 11b vs 11g vs 11n*. URL: `https://www.rfwireless-world.com/Articles/difference_bw_11a_11b_11g_11n.html` (visited on 02/04/2020).

[3] *IEEE_802.11*. URL: https://en.wikipedia.org/wiki/IEEE_802.11 (visited on 02/04/2020).

[4] *IEEE_802.11b-1999*. URL: https://en.wikipedia.org/wiki/IEEE_802.11b-1999 (visited on 02/04/2020).

[5] Houda Labiod, Hossam Afifi, and Costantino de Santis. "Wi-Fi^{TM}, Bluetooth^{TM}, Zigbee^{TM} and WiMax^{TM}". In: Springer, 2007, pp. 281 –291.

[6] Shyam Parekh. *Understanding Wifi Carrier Sense*. 2011. URL: http://www.revolutionwifi.net/revolutionwifi/2011/03/understanding-wi-fi-carrier-sense.html (visited on 02/04/2020).

[7] Shyam Parekh. *Unit 11: IEEE 802.11 Wireless LANs*. URL: https://inst.eecs.berkeley.edu/~ee122/sp07/80211.pdf (visited on 02/04/2020).