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Modelling and Performance Evaluation of Physical Layer of Wireless Regional Area Networks (IEEE 802.22) over AWGN Channel

Mayank Mittal and Jaikaran Singh* and Mukesh Tiwari**

** Department of Electronics & Communication SSSIST, Sehore, (MP), India*

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ABSTRACT : The IEEE 802.22 stands for Wireless Regional Area Network (WRAN). WRAN uses the white spaces & unused VHF & UHF TV Bands. Cognitive Radio (CR) is a key to develop such a wireless standard. It is based on Time division multiplexing and Orthogonal Frequency Division Multiple Access. WRAN is developed for rural areas where utilization can be very low.

In this paper we provide a detail overview of IEEE 802.22 WRANs & mainly PHY layer. The WRAN physical layer is fundamentally based on the IEEE 802.16e system, but the OFDMA parameters including preamble structure and pilot pattern are newly designed by considering the WRAN channel environments. To evaluate the performance of PHY layer of WRAN, we have done simulation of its end to end model in MATLAB and obtained BER curves for uplink direction for different modulation schemes at different code rate over AWGN channel.

Keywords: WRANs, IEEE 802.22, cognitive Radios, OFDMA, PHY Layer, Uplink, BER.

I. INTRODUCTION

According to a report published by the United Nations, more than three billion people are currently living in rural areas [1]. In developing countries like China and India, about 70 percent of the total populations live in rural communities, which are spread far and wide over large geographic areas. For these communities, it is believed that providing communications services is an important step to facilitate development and social equity [2]. Apart from that, rural communications networks are crucial in disaster/emergency response scenarios.

However, providing communications to rural area is always challenging due to higher costs and lower demand. Most rural areas have low demand for services if compared to urban areas. To create a viable business, operators must aim for low-cost solutions. According to circumstances in rural communities such as coverage demands for large areas, installation, establishment, development & maintenance cost of rural communications networks can be costly. [3,4] This is particularly very true for wired networks because wires or cables must be laid all the way to the destinations. So the wireless technologies are usually preferred for rural communication network.

There are various standards developed and are used for the wireless communication. Wireless systems based on IEEE 802 standards such as IEEE 802.11 (WLAN) so-called Wi-Fi and IEEE 802.16 (WMAN) so-called WiMAX are examples of Broad Wireless Access (BWA) systems deployed for local and metropolitan area networks, respectively. Each of these technologies has its advantages and corresponding drawbacks.

Cognitive radio is an emerging technology that promises to overcome one of the most challenging problems of modern wireless communications. IEEE 802.22 (WRAN) is the first wireless standard which works based on Cognitive Radios (CR). Taking advantage of CR technique, fallow TV spectra in the VHF/UHF bands, from 54MHz to 862MHz, are used for wireless services without any harmful interference to primary and incumbent users [5]. WRAN is a fixed Point to Multi-Point system and its connectivity between the Base Station (BS) and the Consumer Premise Equipment (CPEs) is possible in both line-of-sight (LOS) and non-line-of-sight (NLOS) situations. The typical radius for WRAN ranges 30km can cover up to 100 km, through which we can meeting the demands of rural areas. The minimum data rate of the system is 1.5 Mb/s in the downstream (DS) direction, i.e. from BS to CPE, and 384 kb/s in the upstream (US) direction, i.e. from CPE to BS.

II. PHYSICAL LAYER MODEL (BLOCK DIAGRAM)

In order to meet the requirements for the overall 802.22 system, the physical layer maintains a high degree of flexibility. This is built in to the basic specification of the system. The WRAN physical layer is fundamentally based and similar to the IEEE 802.16e system, but it is based on OFDMA scheme in Time Division Duplex (TDD) mode and parameters including preamble structure & pilot patter that are newly designed considering the WRAN channel conditions.

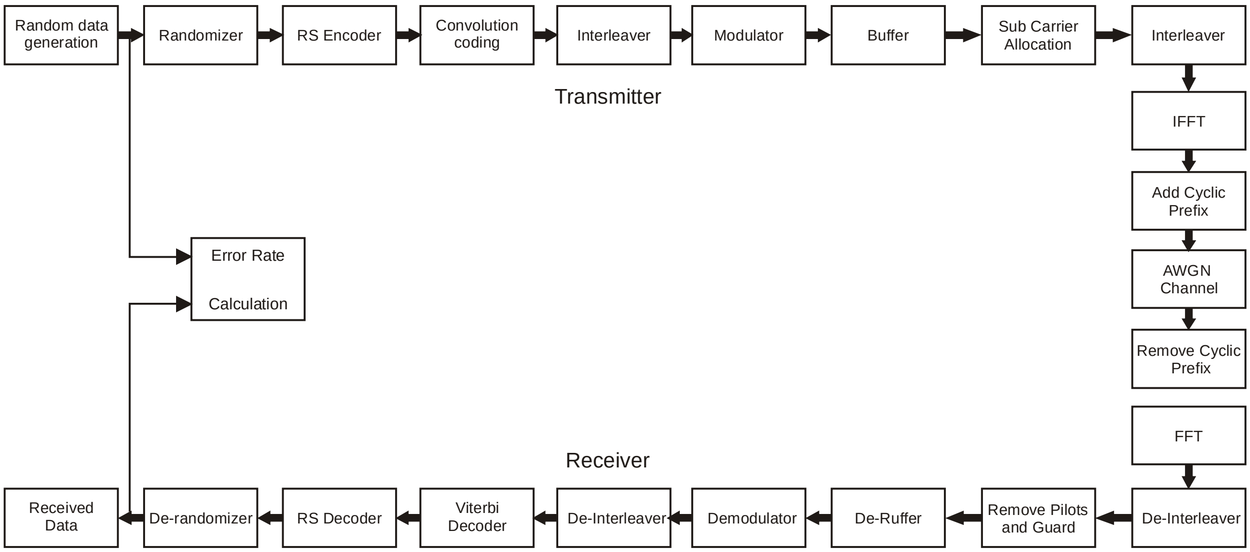

Fig. 1. Physical Layer Block Diagram based on IEEE802.22 WRAN.

Here in this paper we have designed the End to End simulation model of physical layer of 802.22 in MATLAB for US direction [6]. The physical layer mainly consists of three parts: Transmitter, Channel and Receiver. In this paper we have explained the detailed working of transmitter, working of receiver in inverted version of transmitter. AWGN channel is used as testing environment.

As seen from the Fig. 1, random binary data is generated. This scrambled binary sequence is changed to random sequence through randomizer to avoid long sequence of 0's and 1's to improve coding performance. The randomizing is done through XOR operation and 15-bit linear feedback shift register (LFSR). The main component of the data randomization is a Pseudo Random Binary Sequence generator which is implemented using LFSR [7]. The generator defined for the randomizer is given by Equation

$$1 + X_{14} + X_{15} \quad ...(1)$$

This randomized data is then coded for forward error correction using Reed Solomon (RS) code and convolution code. First the RS code is implemented. The Reed-Solomon code is used to add redundancy to the data sequence. This redundancy addition helps in correcting block errors that occur during transmission of the signal. The encoding process for RS encoder is based on Galois Field Computations to do the calculations of the redundant bits. Galois Field is widely used to represent data in error control coding and is denoted by GF (2^m). RS encoder requires two polynomials, one is code generator polynomial $g(x)$ which is used for generating the Galois Field Array and second one is field generator polynomial $p(x)$ used to calculate the redundant information bits which are appended at the start of the output data. These polynomials are defined by the standard [8].

Convolution code is used to correct the random error. A convolution code is a type of FEC code that is specified by CC (m, n, k), in which each in-bit information symbol to be encoded is transformed into an n-bit symbol, where m/n is the code rate ($n > m$) and the transformation is a function of the last k information symbols, where k is the constraint length of the code. Convolution code which shall have a native rate of ½ with a constraint length equals to 7. The other code rates could be obtained by puncturing bits. Till this step the components are set on the basis of 802.16 OFDMA. These coded bits are then delivered to an Interleaver.

Interleaver is basically can be described as a randomizer but it is different from the randomizer, it does not change the state of the bits but it works on the position of bits. Interleaving is done by spreading the coded symbols in time before transmission. The incoming data into the Interleaver is randomized in two permutations. First permutation ensures that adjacent bits are mapped onto non-adjacent subcarriers. The second permutation maps the adjacent coded bits onto less or more significant bits of constellation thus avoiding long runs of less reliable bits.

The first permutation is defined by the formula:

$$mk = \left(\frac{Ncbps}{12}\right) * \bmod(k, 12) + floor\left(\frac{k}{12}\right) \quad ...(2)$$

The second permutation is defined by the formula:

$$s = ceil\left(\frac{Ncpc}{2}\right) \quad ...(3)$$

$$jk = s * floor\left(\frac{mk}{2}\right) + \left(ink + Ncbps - floor\left(\frac{2*mk}{Ncbps}\right)\right)\bmod(s) \quad ...(4)$$

Where,

Ncpc = Number of coded bits per carrier

Ncbps = Number of coded bits per symbol

K = index of coded bits before first permutation

mk = index of coded bits before first permutation

jk = Index of coded bits after second permutation

Same permutation is done on the receiver side to rearrange the data bits into the correct sequence [7].

The interleaved data is sent to the modulator. The digital modulation types used in this standard are QPSK, 16–QAM, and 64–QAM. In modulation data bits are mapped to sub carriers. The buffer puts several burst together that is 5 burst makes 1440 data sub carriers.

Now the pilots are inserted within the data subcarriers. This standard uses a pilot pattern presented in Fig. 2 which is repeated after 7 symbols and 7 subcarriers. Utilizing this pattern, all CPEs within a cell can have good channel estimation after waiting for 7 OFDMA symbols. WRAN system is based on the TDD–OFDMA scheme using the 2048 FFT mode on 6MHz, 7MHz and 8MHz. The subcarriers are classified as data subcarriers (1440), pilot subcarriers (240), guard and DC subcarriers (380).

In the US direction, data subcarriers are again interleaved after the pilot subcarriers are inserted. The pilot sub carrier interleaving is similar to the bit interleaving. However, in the DS direction interleaving is done before pilot insertion [6, 9].

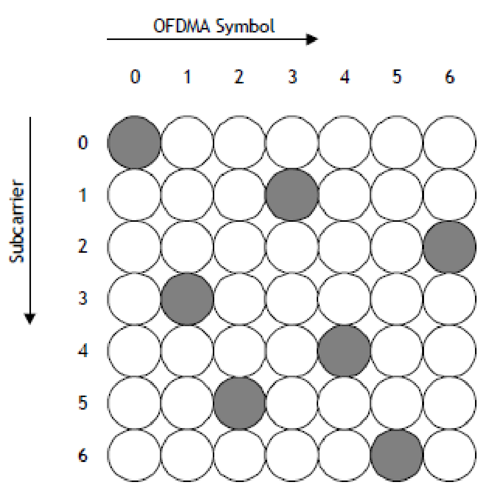

Fig. 2. Pilot insertion pattern.

After insertion of pilot, guard, DC subcarriers & subcarrier interleaving the IFFT is operated on them to create OFDM symbol. Finally, the last part of OFDM symbol, as a cyclic prefix, is added to the beginning. After all these operations, the data are ready to be delivered to the channel [10].

III. ANALYTICAL VERIFICATION AND SIMULATION RESULT

In order to verify the results we have used analytical formulas for un-coded system with AWGN and Rayleigh channel [11]. BER formulas for different modulation schemes are as follows-

$$BER_{64QAM} = 1-\sqrt[3]{1-1.75\times Q\left(\sqrt{\frac{\left(6\log_2^8\right)Eb}{\left(8^2-1\right)No}}\right)} \quad ...(5)$$

$$BER_{16QAM} = \frac{3}{2}\times Q\left(\sqrt{\frac{\left(6\log_2^4\right)Eb}{\left(4^2-1\right)No}}\right) \quad ...(6)$$

$$BER_{QPSK} = Q\left(\sqrt{\frac{2.Eb}{No}}\right) \quad ...(7)$$

Fig. 3 and 4 shows the simulation results of the system for coded BER versus SNR with different modulation schemes at different code rate. AWGN is used as testing environment. As expected with higher modulation schemes with high data rates are more sensitive to SNR degradation. Fig. 3 shows the results over AWGN channel.

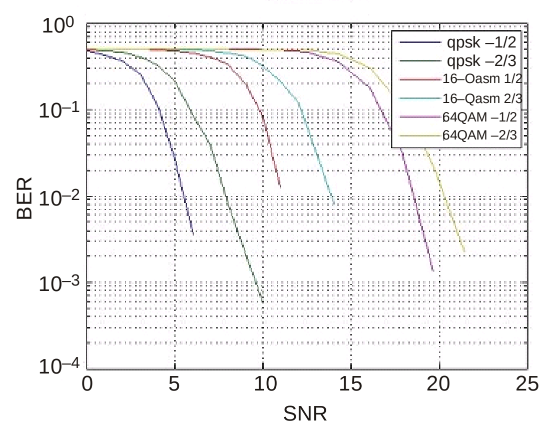

Fig. 3. Coded BER curve for different modulation at different code rates over AWGN channel.

IV. CONCLUSION

In this paper we have done simulation of IEEE 802.22 (WRAN) in MATLAB. We have obtained BER versus SNR curves for different modulation schemes at different code rates. We have tested our result over AWGN. These results help to design an adaptive scheme of WRAN system to adapt the modulation scheme and code rate according the channel state information.

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