Performance Analysis of WRAN at Physical Layer of IEEE 802.22 standardization

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ABSTRACT
In this paper, BER performance of WRAN based on IEEE 802.22 standard is introduced, the performance of physical layer of IEEE 802.22 network is analyzed and simulated over different communication channels. AWGN and multipath fading channels are assumed. BER performance is applied to different types of users and areas. Stationary and mobile users performance is proposed for typical rural and hilly terrain rural area. Different mapping schemes and code rate is presented.

General Terms
Wireless Networks, Cognitive Radio Networks

Keywords
WRAN, IEEE 802.22, Network Performance

1. INTRODUCTION
Due to the huge user demands for wireless communication, Due to lack of spectrum resources, cognitive radio networks are presented to dynamically access the licensed bands on the basis of noninterference with the licensed users. IEEE 802.22 standard considered as the first wireless standard that use cognitive radio ability for broadband wireless applications categorized under Wireless Regional Area Network (WRAN) category [1]. IEEE 802.22 network operates in the white spaces of TV spectrum in VHF/UHF bands targeting remote and rural areas [2].

Basic cell of IEEE 802.22 network consists of base station (BS) and large number of users called Consumer Premise Equipment (CPE), point to multi point communication is used to cover a radius range of (30-100) Km [3].

IEEE 802.22 physical layer (PHY) applies for upstream (US) and downstream (DS) Time Division Duplex (TDD) and Orthogonal Frequency Division Multiple Access (OFDMA) . It uses OFDM as modulation technique, data transmission requires 2K FFT per TV channel [4]. PHY layer of IEEE 802.22 has the ability to adapt its parameters according to available channels and circumstances of CPE which can be either in line of sight (LOS) or non-line of sight (NLOS) with BS. IEEE 802.22 standards use adaptive modulation and code rate according to the communication channel requirements, Convolutional turbo code(CTC), shortened block turbo code (SBTC), and low density parity check code (LDPC) can be used as forward error correction techniques in the standard with code rates of 1/2, 2/3, 3/4, and 5/6 to support different mapping schemes of QPSK, 16QAM, and 64QAM [5].

The rest of this paper is organized as follows:

section 2 shows the related works in this field. In section 3 IEEE 802.22 network PHY layer performance is presented. In section 4 BER performance of IEEE 802.22 is modeled and simulated over different communication channels. Section 5 shows the simulation results. Finally the conclusions is presented in section 6.

2. RELATED WORKS
A number of publications that deal with IEEE 802.22 performance are listed below:

WRAN coverage planning and comparison for different channels is studied in [6].

PHY layer of IEEE 802.22 is modeled and evaluation of BER for different code rates and modulation scheme with noisy channel is presented in [7]. a performance metrics based data channel allocation scheme for IEEE 802.22 is proposed in [8]. Cognitive radio networks as a broadband wireless network s that serves rural and urban area is investigated in [9].

3. IEEE 802.22 PHYSICAL LAYER PERFORMANCE
A typical transmitter and receiver block diagram of IEEE 802.22 network at PHY layer are shown in figure (1). In the transmitter side, the data are submitted to channel coding and pass to the mapper to have the necessary mapping scheme, subcarriers are allocated and pilots are added. Preamble is inserted for synchronization purpose, then the data are converted to parallel and pass to Inverse Fast Fourier Transform (IFFT) and converting again to serial form. Before transmission, cyclic prefix is added to prevent (ISI) then the data convert to RF signal for transmission. In the receiver side, the inverse process are used [10].

4. MODELING AND SIMULATION BER PERFORMANCE OF IEEE 802.22 NETWORKS
The most common performance measurement of any system is the bit error rate (BER) which represents the probability of receiving error bits.

The probability of error (P_e) in OFDM system can be represented as the mean P_e of individual data subcarriers .

$$P_e = \frac{1}{N}\sum_{k=1}^{N} P_e[k] \quad (1)$$

Where: Pe[k] is modulation scheme dependent probability of error for kth subcarrier.

The probability of error for different modulation scheme can be determined as[11]:

$$P_{e-QPSK} = Q\left(\sqrt{\frac{E_s}{N_0}}\right) \quad (2)$$

$$P_{e-MQAM} = \frac{(4-2^{(2-m/2)})}{m} Q\left(\frac{\sqrt{3(E_s/N_0)}}{M-1}\right) \quad (3)$$

Where:

Es is the energy of the symbol.

N0 is the noise power density.

m is the number of bits per symbol.

M is the modulation level and is represented as:

$$M = 2^m \quad (4)$$

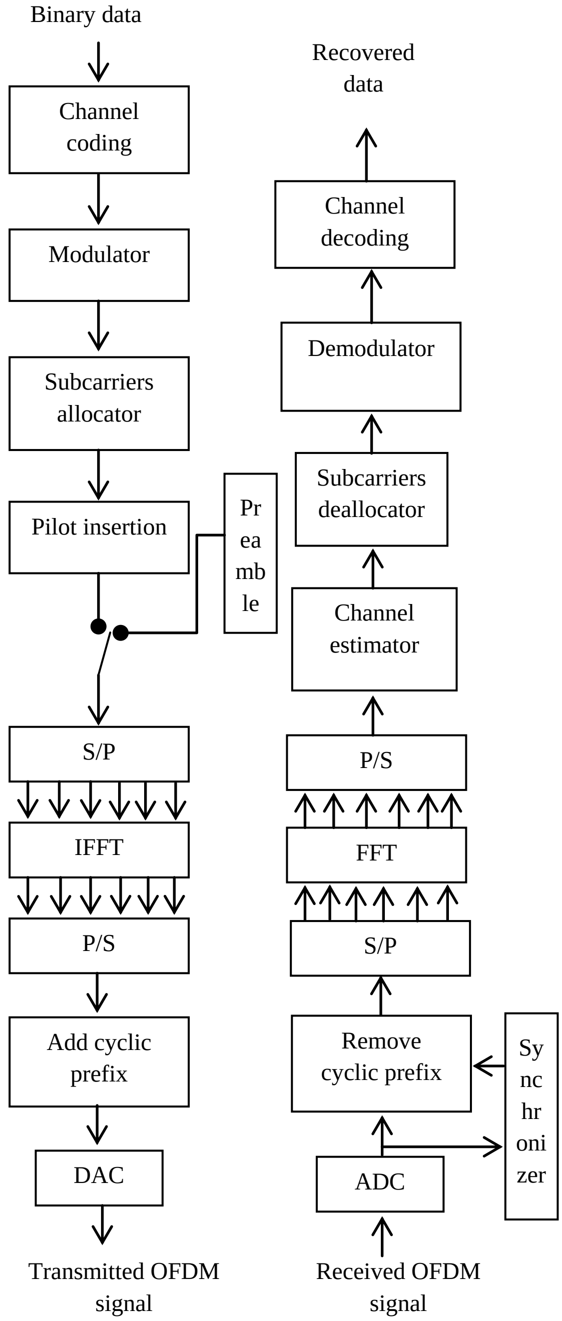

Fig. (1). OFDM transmitter/receiver of IEEE802.22

4.1 Model Assumptions

The simulated model is based on the following assumptions:

1. FFT size is 2048.
2. Three gray code constellation mapping are used which are, QPSK, 16QAM and 64QAM.
3. Cyclic prefix is 1/4.
4. Carrier frequency is 400 MHz.
5. AWGN channel, Rician channel and Rayleigh channel are used.
6. Stationary and Pedestrian mobile are used with speed of 3Km/H.

4.2 Case Study

Three cases for BER are studied and simulated as follows:

1. Stationary users at typical rural area with AWGN channel.
2. Mobile users at rural area with Rician multipath channel.
3. Mobile users at urban area with Rayleigh multipath channel.

5. SIMULATION RESULTS

5.1 BER over AWGN Channel

The performance of IEEE 802.22 over AWGN channel is presented using 2048 FFT and different gray code constellation mapping schemes. 5000 OFDM frame is to be transmitted through the channel. The complex AWGN components are added to the transmitted data . the receiver will perform FFT and demodulation to get the recovered data. BER versus Es/N0 for theoretical and simulated OFDM is shown in figure (2) for the three cases of constellation mapping, QPSK, 16QAM and 64QAM, while figure (3) shows the BER versus E_b/N_0, where Eb is the bit energy.

5.2 BER Over Rician Channel

6 taps hilly terrain rural area with flat fading is analyzed and simulated as Rician multipath fading channel.
Theoretical and Simulated results of Rician channel is shown in figure (4).

5.3 BER over Rayleigh Channel

A flat fading Rayleigh channel is simulated for typical urban area with 12 taps.

Figure (5), shows theoretical and simulated BER performance of IEEE 802.22 network over multipath Raleigh channel.

5.4 BER of Pedestrian and Vehicular Mobile Over Multipath Channel.

Figure (6), shows the BER of pedestrian and vehicle mobiles in IEEE 802.22 network.

The pedestrian mobile speed is 3 Km/H, while the vehicle mobile speed is 100 Km/ H. Both mobiles use the same modulation technique which is QPSK and same cyclic prefix which is1/4 of NFFT under the same channel environments. The center carrier frequency used by both mobiles is 800 MHz, then the Doppler frequency shift for pedestrian mobile is 2.22 Hz, while the vehicle mobile Doppler frequency shift is 74 Hz.The difference of Doppler frequency shift in both mobiles is relatively small which leads to insufficient degradation in BER.

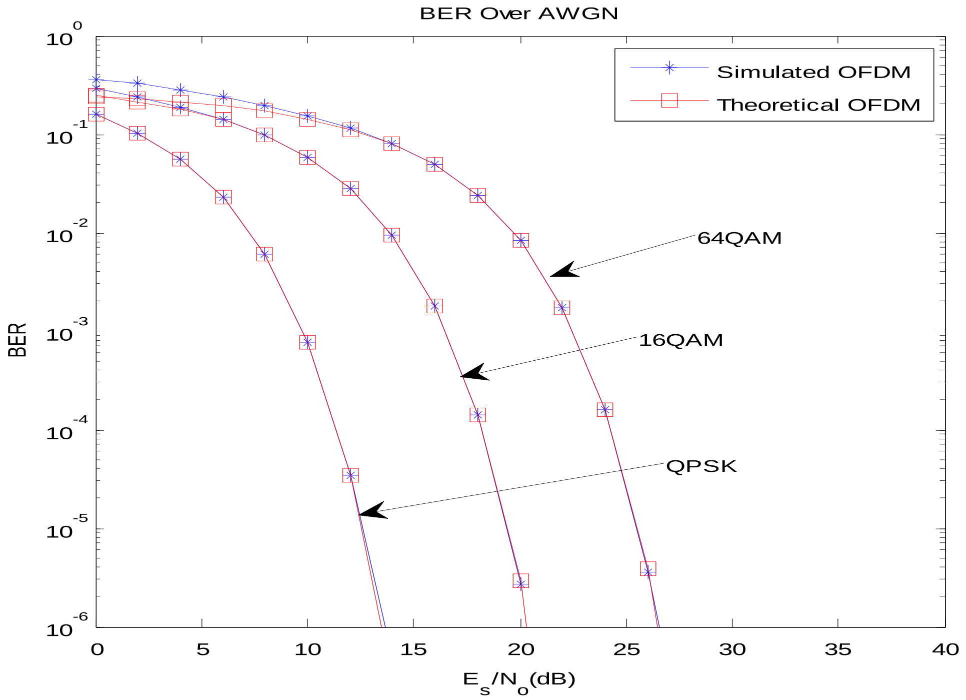

Figure (2). BER of IEEE 802.22 over AWGN channel

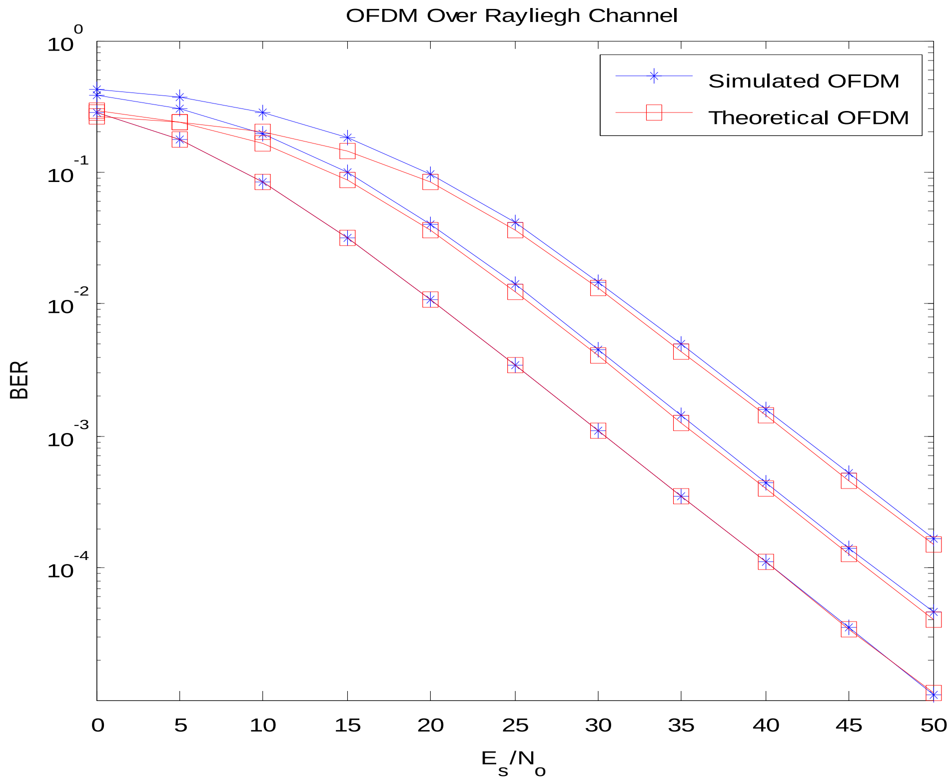

Figure (5). Performance of IEEE 802.22 network over Rayleigh multipath fading channel

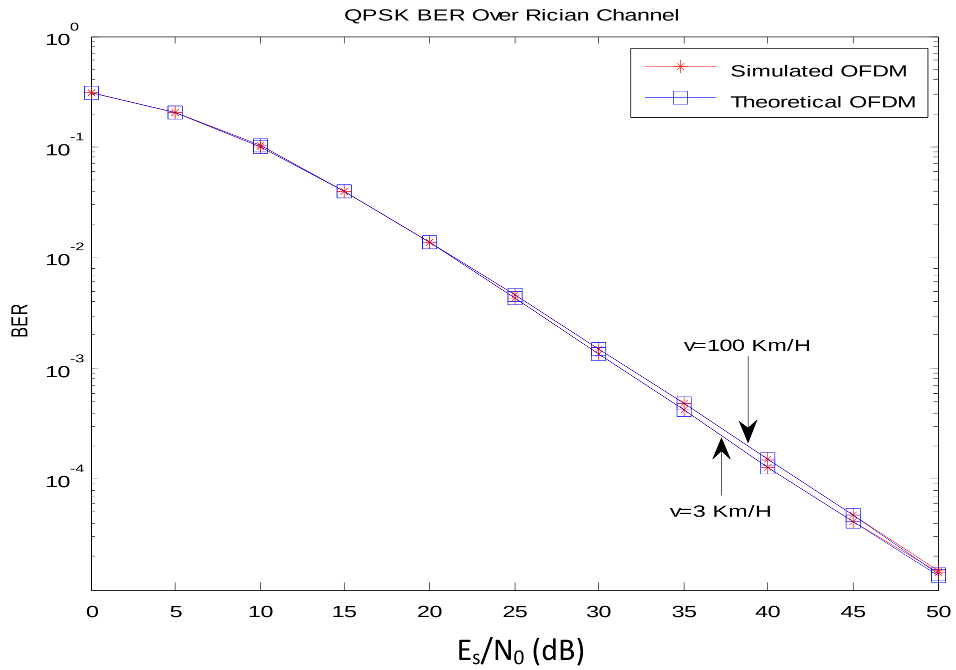

Figure (6). Performance of IEEE 802.22 for pedestrian and vehicle mobiles

Table (1) shows minimum E_s/N_0 required to get BER=10^{-3} for three types of channel AWGN, Rician and Rayleigh, using QPSK modulation.

Table 1. minimum E_s/N_0 for QPSK signal

E_s/N_0 (dB)	AWGN	Rician	Rayleigh
Theoretical	9.758	23.84	30.855
Simulated	9.753	23.838	30.835

6. CONCLUSIONS

In this paper, performance of IEEE 802.22 network has been analyzed and simulated. The results shows a great agreement between theoretical and simulated results.

In data communication system, BER should not exceed 10^{-3} so to keep the performance in this range SNR must be increase.

BER over different channels shows that QPSK scheme is the most robust against error than the other schemes, but it the least bit rate. Where in AWGN channel QPSK required SNR more than 12 dB to achieve BER less than 10^{-3}, while in Rician channel required more than 26dB and in Rayleigh required about 31 dB.

Cyclic prefix is not added to OFDM symbol Over AWGN because there is no ISI.

Increasing cyclic prefix length will increase the overhead in the System.

IEEE 802.22 network has a robustness against Doppler shift due to the operating frequency band.

Increasing FFT size has no effect on BER performance of IEEE 802.22 network over AWGN channel and negligible effect over multipath fading channel.

7. REFERENCES

[1] Hyoil Kim, Student Member, and Kang G. Shin " In-Band Spectrum Sensing in IEEE 802.22 WRANs for Incumbent Protection" IEEE TRANSACTIONS ON MOBILE COMPUTING, VOL. 9, NO. 12, DECEMBER 2010.

[2] Carlos Cordeiro, Kiran Challapali, and Dagnachew Birru "IEEE 802.22: An Introduction to the First Wireless Standard based on Cognitive Radios" JOURNAL OF COMMUNICATIONS, VOL. 1, NO. 1, APRIL 2006.

[3] M.Ravi Kumar, S.Manoj Kumar and M.balajee " A Survey on Rural Broadband Wireless Access Using Cognitive Radio Technology: IEEE 802.22 Wireless Regional Area Networks" Universal Journal of Communications and Network 1(1): 27-31, 2013.

[4] carlos Cordeiro, Kiran Challapali and Monisha Gosh " Cognitve PHY and MAC layers for Dynamic Spectrum Access and Sharing TV Band" ACM , 2006.

[5] Sharad Jain, Raksha Upadhyay " Performance Improvement of IEEE 802.22 WRAN Physical Layer" IOSR Journal of Electronics and Communication Engineering Volume 6, Issue 2 (May. - Jun. 2013), PP 94-98

[6] Priti Subramanium and Rajeshree D. Raut " Improvement of BER on different fading channel using IEEE 802.22 Standard" Open Science Journal of Electrical and Electronic Engineering, 2014.

[7] Mehdi Ahmadi, Ehsan Rohani, Pooya Monshizadeh Naeeni and Sied Mehdi Fakhraie " Modelling and Performance Evaluation of IEEE 802.22 Physical Layer" 2nd international Coference on (ICFCC) 2010.

[8] Saptarshi Debroy Shameek Bhattacharjee and Mainak Chatterjee " Performance based Channel Allocationin IEEE 802.22 Networks" IEEE 22nd International Symposium on Personal, Indoor and Mobile Radio Communications, 2011

[9] Timothy X Brown, Douglas C. Sicker " Can Cognitive Radio SupportBroadband Wireless Access?" 2nd IEEE Symposium on DySPAN, 2007

[10] Apurva N. Mody and Gerald Chouinard " IEEE 802.22 Wireless Regional Area Networks Enabling Rural Broadband Wireless Access Using Cognitive Radio Technology" doc.: IEEE 802.22-10/0073r03, 2010

[11] Mohammed Shweesh Ahmed " OFDM Based T-transform for Wireless Communication Networks"PhD thesis, Newcastle University, UK,2012.