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Adaptive Modulation and Coding Scheme for Physical Layer of Wireless Regional Area Network

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ABSTRACT: To share the frequency spectrum allocated for the other applications is a challenging job which is met by the use of cognitive radio networks. Cognitive Radio (CR) technology permits unlicensed radio transmitters to use licensed bands in absence of primary user. IEEE 802.22 is a new standard for Wireless Regional Area Network (WRANs) operating on cognitive radio technology in the frequency spectrum assigned to television broadcast services. The number of channels in IEEE 802.22 has higher compare to IEEE 802.11 and IEEE 802.16. The physical layer uses the adaptive modulation and coding for enhancing the range. The capacity enhancement of physical layer allows transmitting data efficiently for underlay and overlay subcarrier. In this paper the data transmission efficiency at physical layer of wireless regional area network is analyzed in terms of bit error rate and transmission efficiency or throughput with artificial neural network based adaptive modulation and coding scheme over fading channel. The comparative studies of BER and throughput of adaptive modulation coding based wireless regional area network is performed Further artificial neural network based model of AMC technique has been discussed.

Keywords: Adaptive modulation, ANN, BER, Cognitive radio, SNR, WRAN.

I. INTRODUCTION

The wireless communication system is day by day becomes demanding. It started with Personal Area Network of few meters and now scales to regional area network of few ten of km. The FCC have developed different standard with time. The Fig. 1 shows the evaluation and parameters of different generation of wireless communication.

Cognitive Radio (CR) technology based WRAN, is primarily designed to function in the TV Whitespaces with zero interference with the primary users. The features like sensing and management of spectrum, geo-location, channel sharing, and security are implemented for Cognitive Radio based operation. IEEE 802.22, IEEE 802.22.1, IEEE 802.22.1 standards are considered as a project to develop wireless regional area network to use VHF and UHF band operation in the range of 17 –33 km [1]. The IEEE proposed wireless regional area network IEEE 802.22 standard which uses digital and analog Television frequency band. This is the first standard which is dependent on the cognitive radios spectrum Sensing concept used for maximum utilization of the channels to transmit the information [1, 2] hence it is Optimized for highly frequency selective fading channels. The FCC formulated the TV band notice of proposed rulemaking (NPRM) allowing unlicensed radio channel to use TV broadcasting bands, without causing interference to TV receivers [3]. This can be accomplished by deployment of CR based technologies. The proposed NPRM was released in May-2004. This objective of using TV broadcasting band for WRAN lead to establishment of working group for IEEE 802.22 in 2004, November. This working group aimed to develop an interface i.e PHY and MAC [4, 5] based on cognitive radio to support operation of unlicensed user in TV broadcasting band

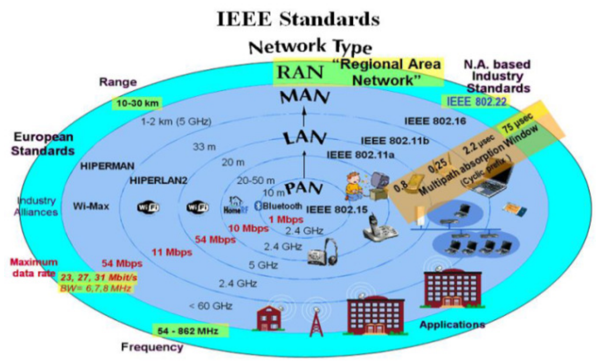

Fig. 1. Different IEEE Standard.

II. PHYSICAL LAYER STRUCTURE OF WRAN: SYSTEM SIMULATION

The uplink transmission of IEEE 802.22 uses OFDMA while orthogonal frequency division multiplexing is used for down link transmission. The quadrature phase shift keying, 16-QAM and 64-QAM modulation scheme is supported due to frequency selective and long distance transmission and in the channel coding part convolution code, Turbo, LDPC, Block Turbo code is supported. In this work, an IEEE 802.22 physical layer has been designed. This is designed for the upstream direction. The physical layer has three parts- Transmitter, receiver and channel. Here the transmitter is taken into consideration. The functioning at the receiver side is an inverted version of the transmitter and for the channel part, Rayleigh fading channel is used.

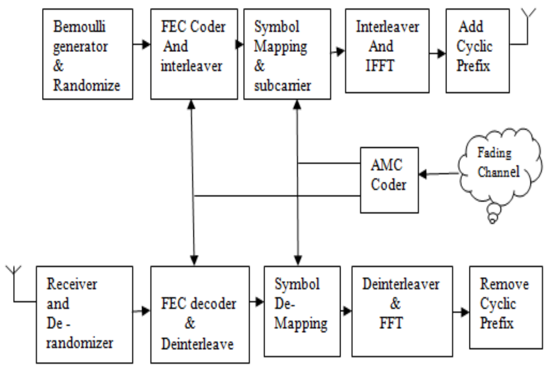

Fig. 2. Physical layer structure of WRAN.

The above system is simulated with two types of adaptive coding scheme in the first scheme adaptive modulation without blocking of transmission is deployed. Here data is continuously transmitted even if the channel is experiencing a deep fading. Under bad channel conditions robust modulation is used and if the channel conditions are good the spectral efficient modulation can be used. The approach is adaptive modulation with blocking the transmission. Here when the channel is under fading conditions, transmission will be stopped. This mode of data transfer is preferred [6, 7] as the channel will be occupied only when the channel conditions are appropriate

A. System Model

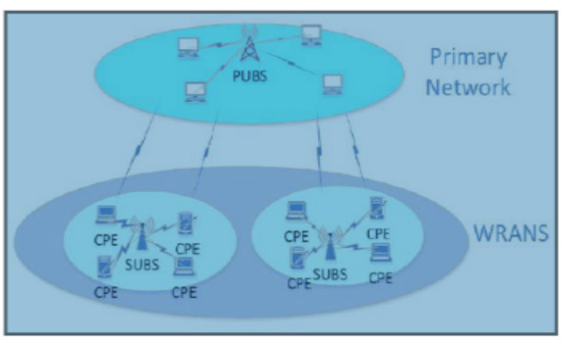

Fig. 3. Functional architecture of WRAN.

The overall architecture of WRAN includes some primary and secondary networks. The primary network consists of users to which a dedicated frequency band is assigned. These users are named as primary users (PU) or licensed users. These includes TV receiver, TV Booster, microphones etc. The secondary network is WRAN which consist of secondary user base station (SUBS) and customer premise equipment (CPE). One SUBS in its service area has control over the associated CPE and it controls the communication between SUBS and CPE [8] One WRAN network supports 512 CPE.

Let us assume that overall network consist of n users ie $n = \{1,2 \ldots. n\}$ trying to send the data to the base station in a cooperative sensing environment [9, 10]. The channel bandwidth B_o is divided in to N subcarriers ie $N = \{1.2 \ldots..N\}$ A user $i\epsilon n$ can send the data over a particular subset of the subcarrier, with P_i as the transmitted power which is the maximum power of individual user and is given as

$$\sum_{i=1}^{n} Pi < Pmax \quad (1)$$

where P_{max} is the maximum power of the channel.

The expression for SINR for the user u over the subcarriers N can be obtained as

$$\gamma_i^N = \frac{P_i^N h_{ii}^N}{n_o + \sum_{j \neq i} h_{ji}^N P_j^N} \quad (2)$$

Where P_i^N is the transmission power of individual user i over the sub-carrier N,$h_{ji}$is the gain of the channel to the receiver of user $i$from user j on the subcarrier N and n_o is the noise power.

The user i can transmit over the subcarrier Nat a rate given by

$$R_i^N = B_o log_2\left(1 + \frac{\gamma_{im}}{r}\right) \quad (3)$$

Where B_o is the sub carrier bandwidth and $r =$ BER requirement [11]. r is further defined as

$$\ln(5BER)/1.5$$

if all the users are arranged in a matrix A of the order of MXK then [12] the total data rate of the user i is obtained as$R_i = \sum_{m=1}^{N} a\, R_i^N$ (4)

The system model shown in Fig. 3 is a cooperative spectrum sensing scenario in which reliability of spectrum sensing can be improved by incorporating spatial diversity such that there is increased probability of detection and decreased probability of false alarm [13, 14]

B. ANN Model for AMC Scheme

An artificial neural network consist of multiple parallel elements stimulated by biological nervous system [15-17]. As the RF signal is dynamic, nonlinear in nature and often it is coupled with noise that results from natural and artificial sources. Hence a fully connected ANN with two hidden layers [18] are used in this study. The Modulation coding scheme of WRAN system has modeled using feed forward neural network (FBNN). This model uses the AMC matrix for training. It has two input BER threshold and SNR value. It provides the modulation order and coding rate as output. The architecture of ANN has shown in Fig. 4.

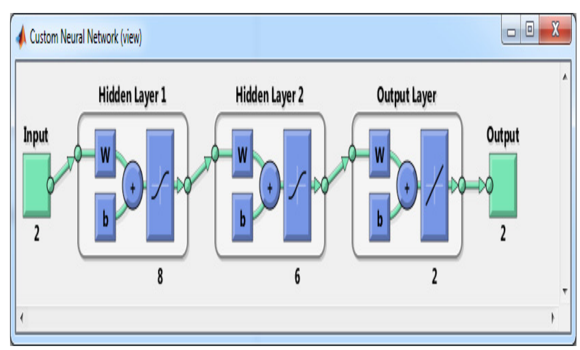

Fig. 4. FBNN structure for the AMC of WRAN.

The input signals and output signals are pre-processed for improving the accuracy of the model with respect to a small datasets available with the AMC matrix. The BER threshold of 10^{-3} and SNR range 10 dB to 25 dB has been taken for training of FBNN. The training curve is shown in the Fig. 5.

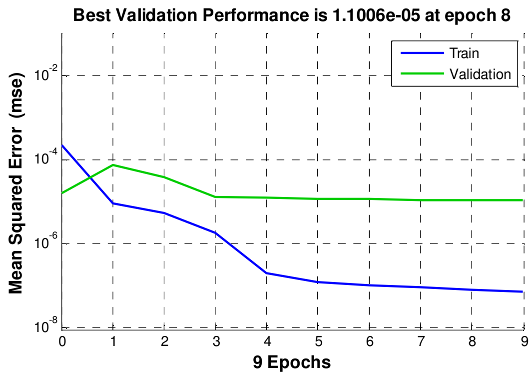

Fig. 5. Training curve of FBNN.

According to concept of WRAN system if a secondary user wishes to use the empty TV channels, it will contact the geolocation data base and sends the request for the list of unused channels [18, 19]. If more than 1 channels are identified as free channel, the SU selects the best channel. The choice of channel selection depends on the performance characteristics viz low BER, low interference and high throughput [20, 21]. If we consider the performance metrics for the probability of appearance of the primary user (PU) and let this matrix is P_{LU}. if $P_{LU} = 1$, it indicate that there is a probability of appearance of the PU in the channel-1.hence the SU has less time to use that channel and it has to make the channel vacant immediately as soon as the primary user (PU) will appear. This results in degradation of the throughput. Let {N} be the set of free channels. The probability *P* and *Q* for the selection of the channels from N can be obtained as

$P = \{n\epsilon N: P_{LU}(n) \geq 0.5\}$ (5)

$Q = \{n\epsilon N: P_{LU}(n) < 0.5\}$ (6)

Therefore it is preferable to use a set of Q channel as the probability of appearance of PU is less hence ANN based channel selection technique is used.

III. RESEARCH METHOD

Table 1: parameters used in simulation.

Parameter	Specification
Modulation	QAM-8,16,64,128
FEC	Convolution code
Cyclic prefix modes	¼
Convolution code	1/2, 2/3, 3/4
Channel	Rayleigh channel
Frequency range	54-862 MHz
Channel Bandwidth (Mhz)	6
Subcarrier Spacing (Hz)	3.348
Total no. of subcarriers,	2048
No. of data subcarriers	1440
No. of pilot subcarriers	240

A. Results and discussion

Standard IEEE 802.22 has defined 12 combinations of three different types of modulations quadrature phase shift keying ie(QPSK), 16-quadrature amplitude modulation ie (16-QAM) & 64-QAM and for data communication four convolution coding rate1/2, 2/3, 3/4 & 5/6) are chosen flexibly to achieve various trade-offs of data transmission rate and robustness, depending on the channel and interference conditions. In this simulation turbo code is incorporated to enhance the error correcting capability of the system. In our work we have added the QAM-128 and reduce the CR =5/6 for enhancing the spectral rate. The choice of modulation and CR has not done only on the basis of BER threshold and spectral efficiency. The graph of spectral efficiency is shown in Figs. 6 and 7. From the Fig. 6 and 7, it is clear that the switching SNR for communication system needs to sense very accurately for finding the modulation and coding rate. The table shown below is used for generating code rate and modulation order for different threshold BER.

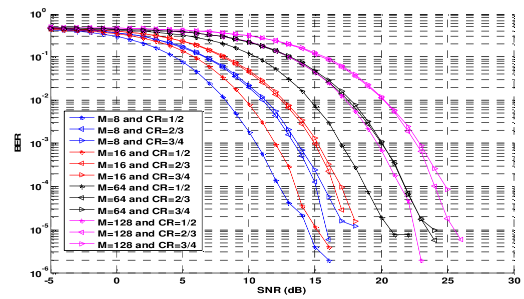

Fig. 6. BER Analysis of WRAN for different modulation And code rate.

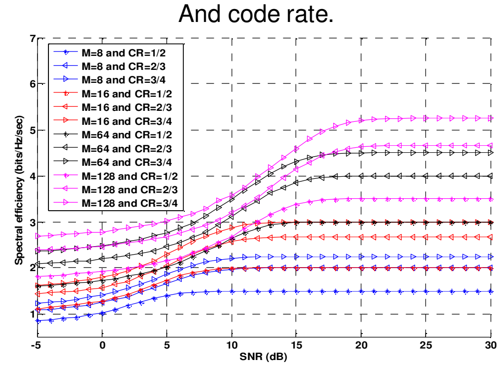

Fig. 7. The Spectral efficiency for different modulation and Code rate.

From the Table 2 and 3 the effective SNR has been choosen based on minimum switching requirement. The modulation table has been reducing based on the maximum workable SNR range and maximum achievable rate.

Table 2: Spectral efficiency for different modulation and code rate.

Modulation Order	Coding rate	SNR	Spectral Efficiency
8	1/2	10	1.499246
8	2/3	13	1.499985
8	3/4	13	1.499985
16	1/2	12	1.499867
16	2/3	14	1.499985
16	3/4	15	1.5
64	1/2	17	1.5
64	2/3	20	1.5
64	3/4	20	1.5
128	1/2	19	1.5
128	2/3	22	1.5
128	3/4	22	1.5

Table 3: Maximum Spectral efficiency for different modulation and code rate.

Modulation Order	Coding rate	Threshold SNR	Max achievable Spectral efficiency
8	1/2	10	1.5
16	1/2	12	2
8	3/4	13	2.25
16	2/3	14	2.666667
16	3/4	15	3
64	1/2	17	3
128	1/2	19	3.5
64	3/4	20	4.5
128	3/4	22	5.25

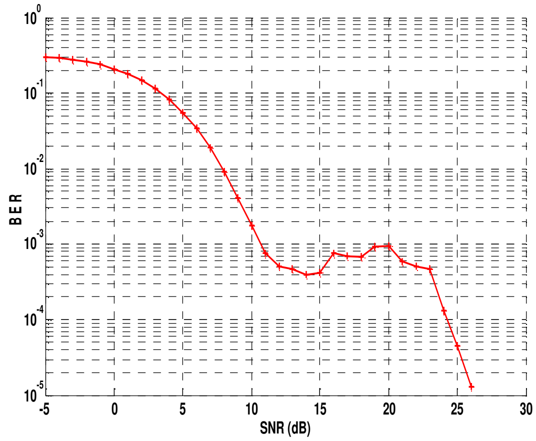

Fig. 8. BER Performance of AMC based WRAN.

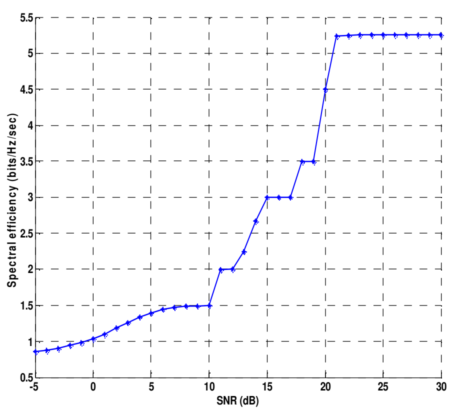

Fig. 9. Spectral efficiency of AMC based WRAN.

The BER and spectral efficiency for AMC based WRAN system is shown in the Figs. 8 and 9. As shown in Fig. 8 with increase in SNR the BER goes on reducing. Similarly, as shown in Fig. 9. The number of SNR switching may further have reduced by taking the measured SNR variation of > 2 dB.

The comparative plot of the modulation order with AMC matrix and ANN has been given in the Fig. 10 for different SNR value. The outputs of ANN are suitably threshold for modulation order and coding rate. The output of ANN are exactly matched with the AMC matrix.

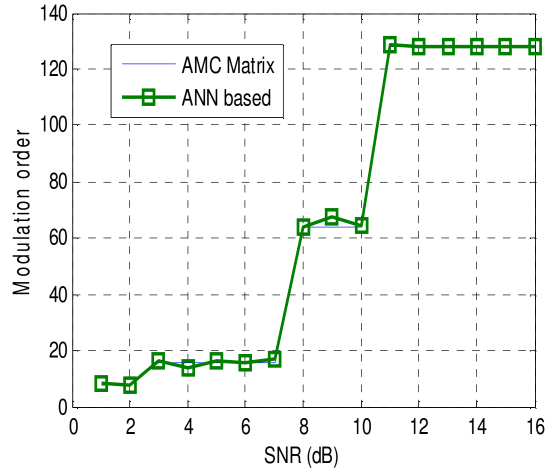

Fig. 10 (a) Graph of SNRV/S Modulation order.

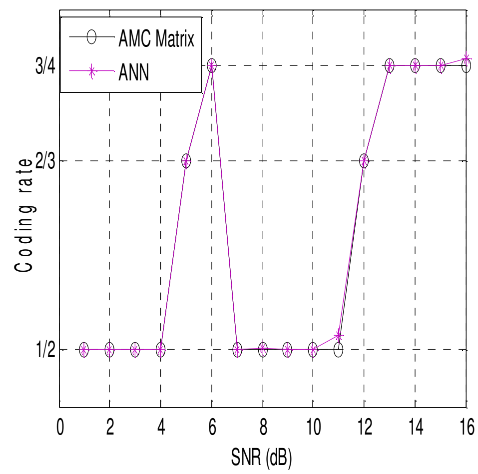

Fig. 10 (b) Graph of SNR V/S Coding rate.

IV. CONCLUSION

The first worldwide standard which is based on cognitive radio technology is defined by IEEE802.22 working group. This standard functions in the TV white space, makes use of techniques such as sensing and management of spectrum and detection and avoidance of incumbent to achieve effective coexistence which will further allow sharing of radio resource with existing licensed services. In this work the physical layer of IEEE 802.22 has been modeled for use of turbo code for AMC. BER and throughput has been analyzed for AMC based system. The use of turbo code in the AMC allows the higher modulation at low SNR, hence it offer to use the QAM128 and QAM512 also. The AMC with QAM128 has been presented in this paper with maximum spectral efficiency of 5.25 bits/Hz/sec which is higher than the earlier AMC which is 5 bits/Hz/sec for SNR >22 dB. The ANN based AMC concept has also developed successfully. This concept is adaptive in nature and offer many advantage over time varying behavior of wireless system

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