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DECISION BASED SPECTRUM SENSING USING NEURAL NETWORKS

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ABSTRACT

Cognitive Radio (CR) is a radio that has the potential to alter its transmission parameters based on spectrum availability. The word Cognitive means "Intelligent" and the word radio means this system works in the radio frequency range i.e. from 3KHz to 300GHz.

In the conventional radio system spectrum availability is checked on fixed intervals of time. In this mechanism spectrum availability cannot be checked prior to the time even spectrum is free. As a result spectrum is not being properly utilized. In CR the time of spectrum sensing is based on various network parameters such as energy, threshold voltage etc. Therefore, in CR interval of time is dyanamic and time of spectrum utilization is more when compared to the conventional radio system

***Keywords*– Channel status, Cognitive radio, Probability of false alarm, Probability of detection, Spectrum Sensing.**

I. INTRODUCTION

In wireless communication data is propogated in the form of electromagnetic waves. With the advancement of wireless technology, its applications have increased significantly. Due to increase in demand of wireless services there is a need of more and more spectrum. Spectrum is the entire range of frequencies from Radio waves (lowest frequency) to Gamma rays (highest frequency). Spectrum is divided into different frequency bands and each frequency is assigned for a specific application [1]

Dynamic spectrum access (DSA) has been proposed as an alternative policy to allow the radio spectrum to be more efficiently utilized [2]. Using DSA, a portion of the spectrum can be licensed to one or more users, which are called primary users; however, the use of that spectrum is not exclusively granted to these licensed users, although they have higher priority in using it. The unlicensed users, which are referred to as secondary users, are allowed to opportunistically utilize the unused licensed bands, commonly referred to as "white spaces" or "spectrum holes", as long as the primary users' transmissions can be adequately protected. By doing so, the radio spectrum can be reused in an opportunistic manner or shared all the time which can significantly improve the spectrum utilization efficiency [3].

The federal communications commission has already expressed its interest in permitting unlicensed access to white spaces in the television (TV) bands [4]. This interest stems in part from the great propagation characteristics of the TV bands and their relatively predictable spatio-temporal usage characteristics. To reliably identify the white spaces, some methods that the secondary users can employ are: geolocation combined with access to database, beacons, spectrum sensing or a combination of any of those methods [5, 6].

In the geolocation method, primary users register the relevant data such as their location and transmit power as well as expected duration of usage at a centralized database. Secondary users then have to access this database to determine the availability of white spaces at their location. In the beacon method, secondary users only transmit if they receive a control signal (beacon) identifying vacant channels within their service areas. Without reception of this control signal, no transmissions are permitted by the secondary users.

There a for mentioned methods require some modifications to the current licensed systems and their deployment is costly. In addition, with these methods, secondary devices will need additional connectivity in a different band in order to be able to access the database [5] or a dedicated standardized channel will be needed to broadcast the beacons [6]. In the spectrum sensing method, secondary users autonomously detect the presence of the primary signals and only use the channels that are not used by the primary users. Due to its low infrastructure cost and its compatibility with the primary systems, we adopt the spectrum sensing.

In this paper, we propose an algorithm with artificial intelligence for spectrum sensing hence determine the occupancy status of a channel, thus enabling opportunistic spectrum access. Recently, Artificial Intelligence (AI) based methods are also receiving significant research attention. It has been seen that AI forms the basic core of the cognitive engine that may be conveniently used for the improvement of certain QoS parameters of wireless communication system via cognizance.

Hard decision based spectrum sensing techniques predicts the channel status based on certain threshold value. Since the nature of the problem is nonlinear and channel status does not depends on any single parameter. The aforementioned issue necessitates the need of soft decision based architecture that can consider multiple parameters and combine them in a meaningful output.

The main objective of this paper is to find the shortcomings of hard decision based spectrum sensing and to develop a neural network based soft decision spectrum sensing algorithm to remove such deficiencies.

II. COGNITIVE RADIO AND SPECTRUM SENSING

2.1 Cognitive Radio

"Cognitive radio is a radio of an intelligent wireless communication system that senses and is aware of its surrounding environment and capable to use or share the spectrum in an opportunistic manner without interfering the licensed users" [7].

Cognitive Radio (CR) technology is an intelligent wireless communication network with the following characteristics: It uses different techniques to become aware of the surroundings, have the abilities to learn from the outer environment and can change the parameters of the transmitted and received data to achieve the goal of effective communication without interference. The most important function of a CR is spectrum sensing, where the secondary user (unlicensed user) can utilize the available spectrum of the licensed user (primary user) with the condition that, the SU will vacant the spectrum for the primary user.

For the detection of presence or absence of the licensed user, two schemes are used: centralized and distributed schemes. In a centralized scheme, a signal is sent to the common controller which makes the decision and informs the secondary user. On the other hand in distributed scheme, all the secondary users make their

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individual decisions and share them in the neighbourhood, so that the unlicensed user is aware of the status. The basic operation of the CR [8] is, to learn from the surroundings and check the status of the spectrum of the primary user being used or not. In the spectrum sensing process, first, information, is gathered from the radio environment, then the cognitive controller analyzes the information to make a decision about the presence or absence of the primary user, as shown in Figure 1

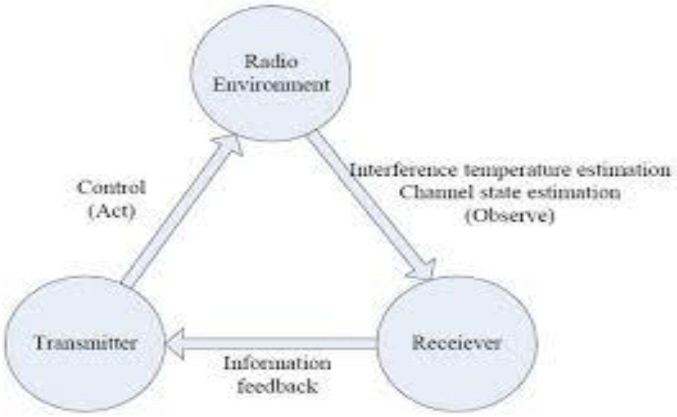

Figure 1: Cognitive radio process [7]

2.2 Spectrum Sensing

In wireless communication, demand of the radio spectrum is increasing. The resources of the radio spectrum are not enough to catch the increasing demands of the users. The recent research shows that, 80% to 85% of the total spectrum is remains unutilized, while only 15%-20% of the spectrum is in use for the maximum period of time. Because the licensed user do not utilize all the available spectrum at any given time. Hence, it is possible to find the unoccupied frequency spectrum band that is not utilized by the licensed user at any certain time. Spectrum sensing is the most important function of the CR.

It is very important for the efficient spectrum sensing to determine either the PU is present or absent. The CR achieve the spectrum intelligence from the environment and it can adapt the new parameters according to the situation. There are two types of the radio spectrum i.e. licensed spectrum and the unlicensed spectrum. The licensed spectrum is a specific band of the radio spectrum, which is sold to a user for the specific service. These specific bands of the spectrum are always reserved. The unlicensed spectrum bands are not reserved and there are some open spaces among the licensed frequency bands those can be used by many different unlicensed users [7].

The process of determining the free (unused) spectrum of the primary user without making any interference and disturbing the rights of licensed user is called as spectrum sensing. It is the key function of the CR which is used to sense the unused spectrum (spectrum holes). These spectrum holes are also referred as black holes or white spaces [9]. Due to the scarcity of the spectrum, it is require to fully utilize the available spectrum. Spectrum sensing can be further divided into some methods. The cooperative spectrum sensing is one of them.

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III. PROPOSED METHOD

3.1 Hard Decision Spectrum Sensing

3.1. 1 Energy Detection

Energy detection (ED) is the most optimal choice for the spectrum sensing where it is difficult for the

CR to get the adequate information about the licensed user waveform. The ED is the most suitable choice when the CR has information about the power of the random Gaussian noise. The basic approach behind this technique is the power estimation of the licensed user (primary user) signal. In this technique, energy of the desired transmitted signal is detected then this detected energy is compared with a threshold value. The threshold is a pre-defined value. If the detected energy is below than threshold value then it is pretended that the licensed user is not present and the spectrum is free. Oppositely, if the detected energy is above the threshold value then it is assume that the spectrum is not free.

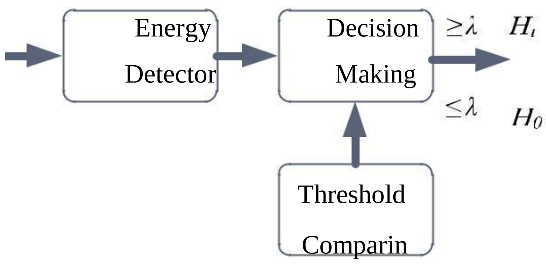

Figure 2: A Block Diagram of the Energy Detection [10]

3.1.2 Limitations of Energy detector

- It is impossible to make distinguish between different primary users because energy detector is not able to differentiate between the sources of the received energy [11].
- It cannot be used for the detection of spread signals [12].
- The computation of the threshold value used for detection is highly susceptible for the variation of the noise levels which leads to a low SNR environment [12].

3.2 Soft Decision Spectrum Sensing

3.2 .1 Neural Network based Spectrum Sensing

This research work proposes a neural network based spectrum sensing method to recognize vacant spectrum. Parameters used for soft decision based spectrum sensing are; channel capacity, signal to noise ratio (SNR), spectral efficiency of the scanned channel and distance 'd' which is the distance between primary and secondary users (In this research work 'd' ranges between 100m-2000m). These parameters are considered as input for Neural Network. Proposed Neural Network based spectrum sensing predicts the status of channel as '0' for vacant channel and '1' for non-

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vacant channel. All the input parameters are explained in the following subheadings.

3.2.2 *Signal to Noise Ratio*

Since, the received power at a receiver is dependent on the pathloss exponent, transmit power and the distance between the transmitter and receiver.

Suppose is received power, is transmit power, 'd' is the distance between primary and secondary users and n is pathloss exponent then the received power is expressed as [13]:

$Pr\ (d) = Pr(d0/d)\ n\ for\ d0 = 10m$ (1)

Let the noise power spectral density $N0$ is assumed as 10−9 W/Hz and bandwidth (B) is 8 MHz and $d0$ is the reference distance. For received power (Pr) equal to 50 KW, n=3andistance d=200 m SNR will be [13]:

$$SNR = Pr\ (d)\ /N0B \quad (2)$$

3.2.3 Channel Capacity

Status of a channel is exceedingly reliant on a parameter known as channel capacity. In general, the rate of transmission over the channel is known as channel capacity. If the channel capacity of a channel with bandwidth B and SNR is given as [13]:

$$C = B\ \log 2(1+ SNR) \quad (3)$$

Equation (3) clearly suggests that if channel capacity decreased then the SNR also decreases. Noise power is high in case of vacant channel and so the channel

capacity will lessen. As per Shannon, channel capacity is also a measure of mutual AWGN Channel X(t) AWGN Signal Energy Detector Threshold Comparing Decision Making information $I(X;\ Y)$; and entropy (H) over all possible inputs [13].

$C = maxp(x)I(X;\ Y) = [H(X) -H(Y|X)]$ (4)

Where X is the input and Y is the output. The channel capacity increases as the entropy increases. Proposed neural network model is placed at 200m apart from the transmitting user. To estimate the status of channel, the channel capacity is provided as an input to neural network along with other parameters. It is noteworthy that the SNR will reduce if the distance between primary and secondary user increases. Therefore the channel capacity will also decrease even though the channel is transmitting. Consequently, the threshold of channel capacity at which the channel is confirmed as vacant is reliant on the distance 'd'.

3.2.4 Spectral Efficiency

The spectral efficiency exhibits how efficiently the allotted spectrum is used. It is the throughput data rate per hertz in a given spectrum.

$$\eta = R/S \text{ bps/Hz} \quad (5)$$

Where R is the data rate in bit/sec and S is the spectrum allotted for the signal. Here R is the channel capacity (C), i.e. the transmission rate over the channel. The spectral efficiency is calculated as [26]:

$$C/R = \log 2(1 + SNR) \quad (6)$$

If the channel is not transmitting any data then the spectral efficiency is less and if the spectral efficiency is below a certain threshold then the channel is deliberated as vacant. A decision making threshold has to be set for

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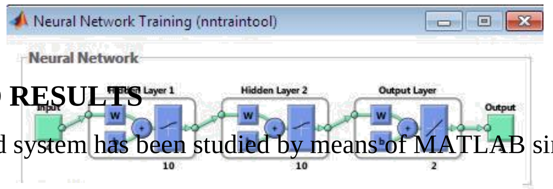
channel capacity above which the channel is considered as non-vacant and below it the channel is considered as vacant [13]

IV. SIMULATION AND RESULTS

The performance of proposed system has been studied by means of MATLAB simulation.



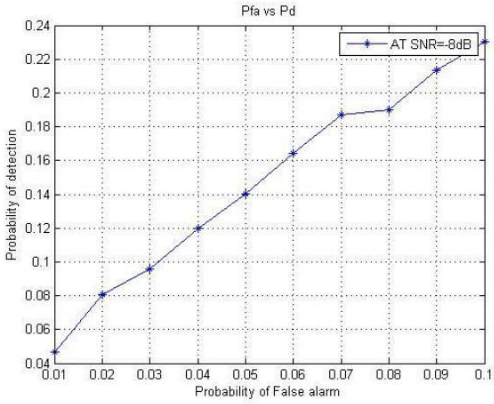


Figure 3: Probability of false alarm V/S probability of detection at SNR= -10

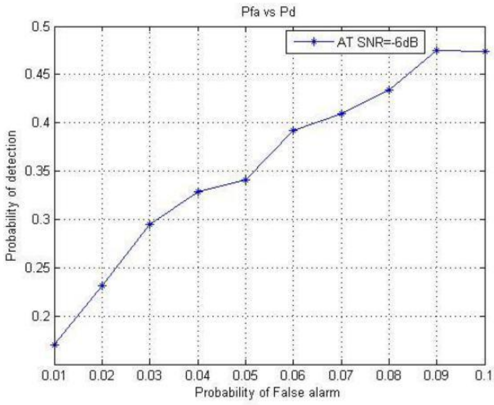


Figure 4: Probability of false alarm V/S probability of detection at SNR= -8 dB

Figure 6: Neural Network training

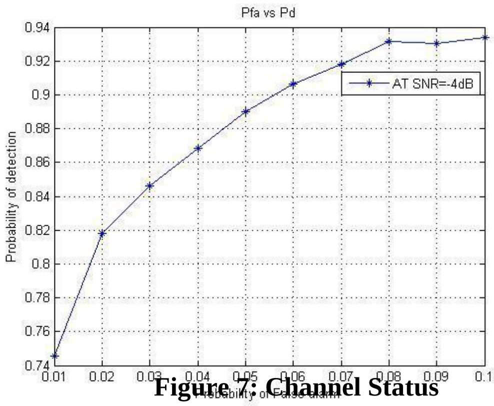


Figure 7: Channel Status

Figure 5: Probability of false alarm V/S probability of detection at SNR= -6 dB

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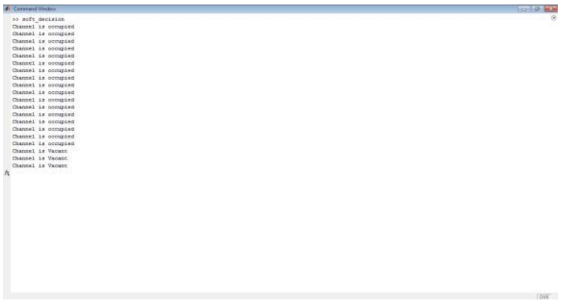

Figure 8 Final Output at command prompt

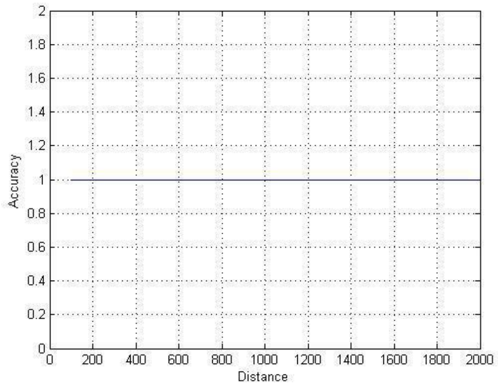

Figure 9: Distance V/S accuracy curve for soft decision spectrum sensing

V. CONCLUSION

Spectrum is a very valuable resource in wireless communication systems and it has been a major research topic from last several decades. Sensing provides awareness regarding the radio environment so that the spectrum opportunities can be efficiently reused while limiting the interference to the primary user. In this paper, we present a new ANN based model that is able to identify occupancy status of a given channel in the spectrum with a view to subsequent ability following the CR concept. Essentially a prediction algorithm is proposed here for the identification of the spectrum hole that could be allotted to the aspiring SU. The occupancy is determined by examining some channel parameters, e.g. SNR, channel capacity, BW efficiency and distance (d). The proposed algorithm indicates channel status occupancy in a quantized index form (0, 1) after appropriate training of the ANN engine.

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