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Soft Decision based Spectrum Sensing for Cognitive Radio Networks

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Abstract –**Spectrum scarcity is a major issue in front of emerging wireless applications. Cognitive radio is a potential solution to the spectrum scarcity problem, where the available spectrum band is shared among several unlicensed users on a non-interference basis. These unlicensed users monitors the available spectrum for "white space". The process of monitoring is done through spectrum sensing. This paper is focused towards the development of hard decision and soft decision spectrum sensing technique. Simulation is carried out on MATLAB 2012b and performance has been compared based on probability of false alarm, probability of detection, channel status.**

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

I. Introduction

One application within the world of software defined radio is spectrum sensing. Spectrum sensing is part of a bigger system called cognitive radio, which is a radio that can modify various parameters autonomously for communication purposes without the need for user intervention. Spectrum sensing is the first stage in cognitive radio in which the radio scans a section of the frequency spectrum for any active signal. There are two main applications of spectrum sensing: Scanning for white space, and scanning for signals. These two applications are closely associated with each other. The former is typically for a transmitter design where the system looks at a range of frequency spectrum and uses internal algorithm to decide if there is any white space, and if so, where is it in the spectrum. This allows the system to transmit without interfering another existing signal at the same frequency. The latter is more commonly found in a receiver system where the purpose is to detect any active signal. These two parts form a complete transceiver system.

Driven by the proliferation of new wireless services and applications, as well as the steadily increasing number of wireless users, the demand for radio spectrum has increased dramatically. The government regulatory agencies employ an inflexible spectrum management approach by granting each operator an exclusive license to operate in a certain frequency band. With most of the prime radio frequency spectrum already exclusively assigned, it is becoming exceedingly hard to find vacant bands to either deploy new services or enhance existing ones. However, this spectrum scarcity is mainly due to inefficient fixed frequency allocations rather than a physical shortage in the spectrum. In fact, the federal communications commission (FCC) has reported the temporal and geographic variations in spectrum utilization to range from 15% to 85% [1]. This inefficiency in the spectrum usage necessitates a new communication paradigm to exploit the existing wireless spectrum opportunistically.

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

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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.

The aforementioned 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

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 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.

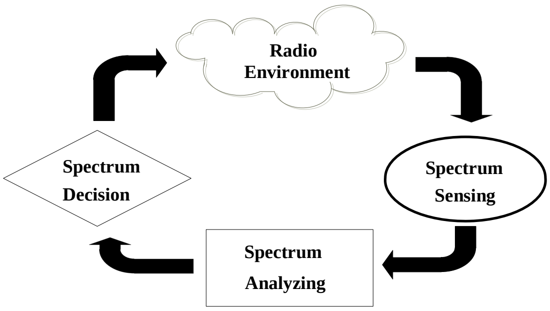

Figure 1: Cognitive radio process [7]

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

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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.

III. Proposed Method

Hard Decision Spectrum Sensing

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.

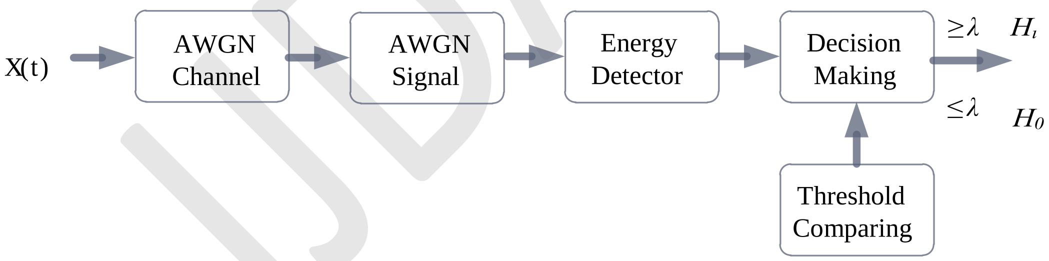

Figure 2: A Block Diagram of the Energy Detection [10]

Limitations of Energy detector

- The require time to achieve the desire probability of detection may be higher.
- The detection performance depends on the uncertainty of the noise.
- 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].

Soft Decision Spectrum Sensing

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-

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

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

$$P_r(d) = P_r(d_0/d)^n \; for \; d_0 = 10m \qquad (1)$$

Let the noise power spectral density N_0 is assumed as 10^{-9} W/Hz and bandwidth (B) is 8 MHz and d_0 is the reference distance. For received power (P_r) equal to 50 KW, n=3 and distance d=200 m SNR will be [13]:

$$SNR = \frac{P_r(d)}{N_0 B} \qquad (2)$$

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]:

$$C = B \log_2(1 + SNR) \qquad (3)$$

Equation (3) clearly suggest 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 information $I(X;Y)$; and entropy (H) over all possible inputs [13].

$$C = max_{p(x)} I(X;Y) = [H(X) - H(Y|X)] \qquad (4)$$

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'.

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.

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

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]:

$$C/R = \log_2(1 + SNR) \qquad (6)$$

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 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.

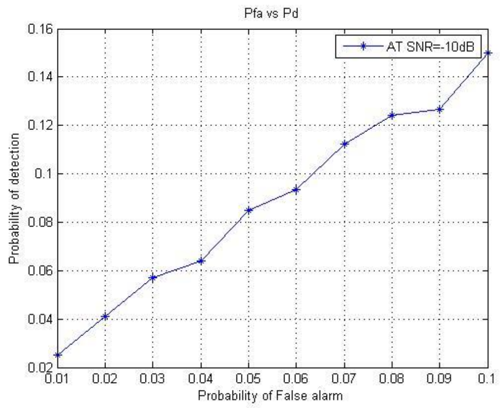

Figure 3: Probability of false alarm V/S probability of detection at SNR= -10 dB

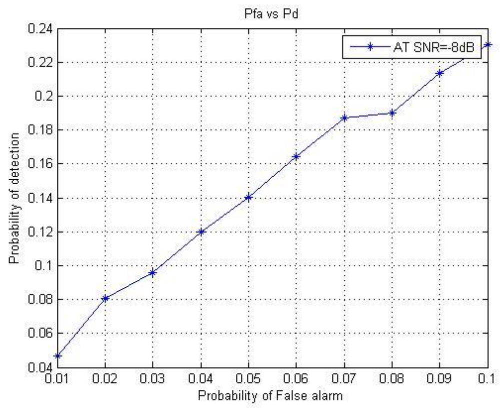

Figure 4: Probability of false alarm V/S probability of detection at SNR=-8 dB

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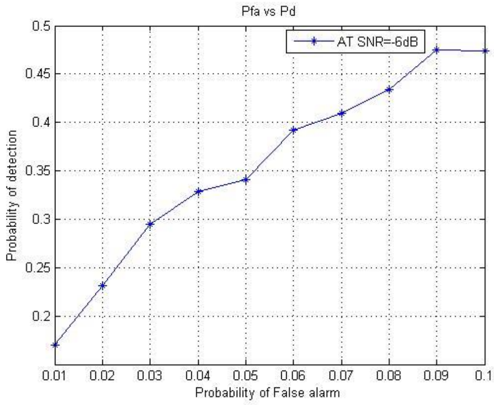

Figure 5: Probability of false alarm V/S probability of detection at SNR=-6 dB

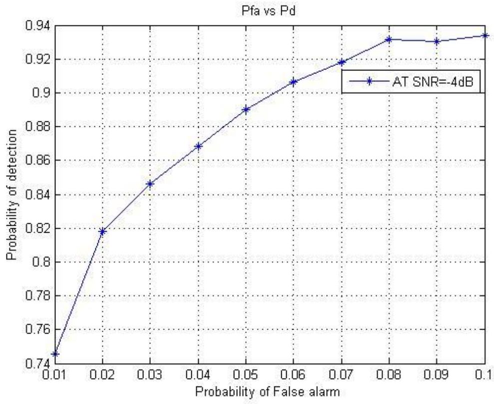

Figure 6: Probability of false alarm V/S probability of detection

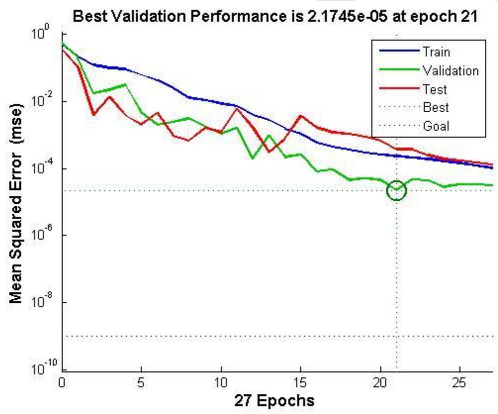

Figure 7: Neural Network Performance plot

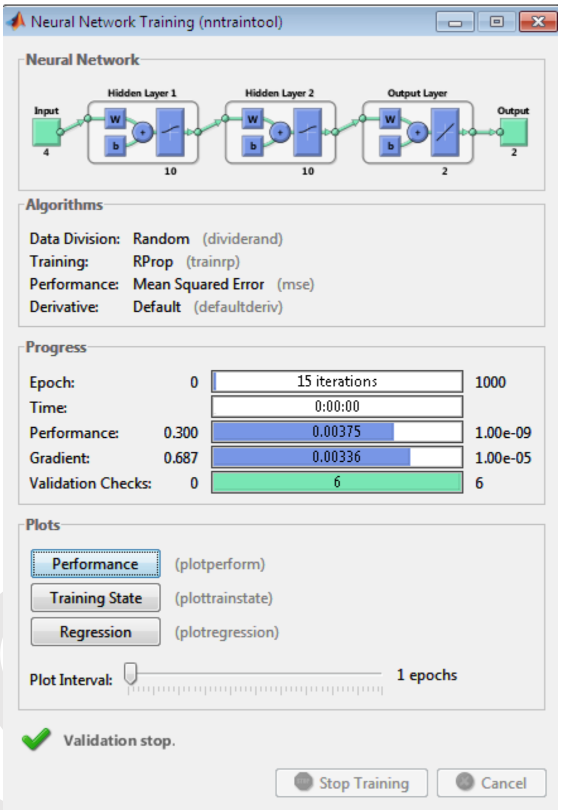

Figure 8: Neural Network training

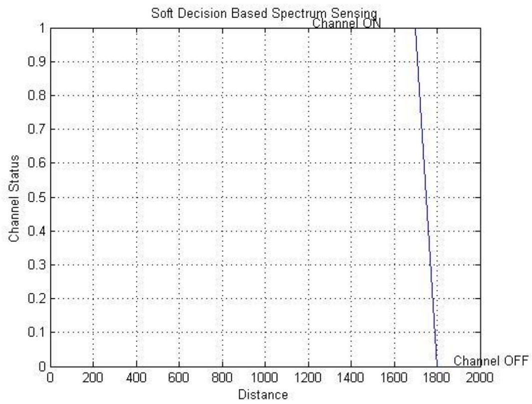

Figure 9: Channel Status

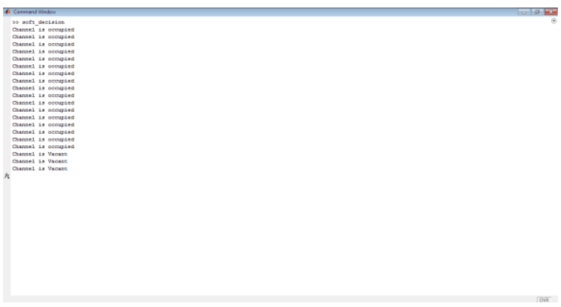

Figure 10: Final Output at command prompt

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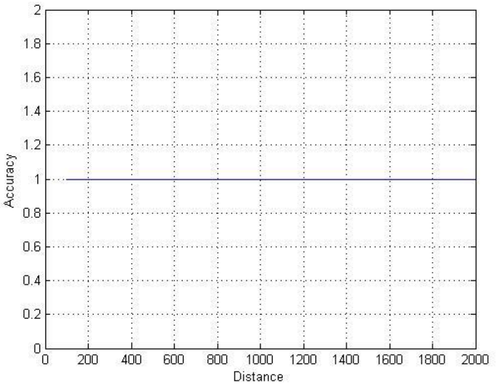

Figure 11: Distance V/S accuracy curve for soft decision spectrum sensing

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.

Reference

[1] Federal Communications Commission, "Spectrum Policy Task Force Report," ET Docket no. 02-135, November 2002.

[2] I. Mitola and J. Maguire, "Cognitive Radio: Making Software Radios More Personal," IEEE Personal Communications Magazine, vol. 6, no. 4, pp. 13–18, August 1999.

[3] Y. Liang, K. Chen, G. Y. Li, and P. Mhnen, "Cognitive Radio Networking and Communications: An Overview," IEEE Transactions On Vehicular Technology, vol. 60 , no. 7, pp. 3386–3407, September 2011.

[4] Federal Communications Commission, "Notice of Proposed Rulemaking, in the Matter of Unlicensed Operation in the TV Broadcast Bands (ET Docket no. 04-186) and Additional Spectrum for Unlicensed Devices below 900 MHz and in the 3 GHz Band (ET Docket no. 02-380)," Tech. Rep. FCC 04-113, May 2004.

[5] M. Nekovee, "Cognitive Radio Access to TV White Spaces: Spectrum Opportunities, Commercial Applications and Remaining Technology Challenges," IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks, Singapore, pp. 1–10, April 2010.

[6] A. Ghasemi and E. S. Sousa, "Spectrum Sensing in Cognitive Radio Networks: Requirements, Challenges and Design Trade-offs," IEEE Communications Magazine, vol. 46, no. 4, pp. 32–39, April 2008.

[7] Awais Salman Qazi, Muhammad Shoaib, Muhammad Shahan Saleem, "Performance Analysis Of Hybrid Decode-Amplify Forward Relaying Protocols In Cognitive Networks", Arkiv EX - Blekinge Tekniska Högskola, 2012.

[8] M. Nekovee, "Quantifying the Availability of TV White Spaces for Cognitive Radio Operation in the UK," IEEE International Conference on Communications Workshops, pp. 1 –5, 2009.

[9] S. M. Alamouti, "A simple transmit diversity technique for wireless communications," IEEE Journal on Selected Areas in Communications, vol. 16, no. 8, pp. 1451 –1458, October 1998.

[10] W. Ejaz, N. ul Hasan, S. Aslam, and H. S. Kim, "Fuzzy Logic Based Spectrum Sensing for Cognitive Radio Networks," 5th International Conference on Next Generation Mobile Applications, Services and Technologies (NGMAST), pp. 185 –189, 2011.

[11] Nisha Yadav, Suman Rathi, "Spectrum Sensing Techniques: Research, Challenge and Limitations", 2011.

[12] Ian F. Akyldiz, Brandon F.Lo, Ravi Kumar Balakrishnan, "Cooperative Spectrum Sensing in Cognitive Radio networks: A Survey", Physical communication, 2011.

[13] Pattanayak, Sandhya, Palanaindavar Venkateswaran, and Rabindranath Nandi. "Artificial Intelligence Based Model for Channel Status Prediction: A New Spectrum Sensing Technique for Cognitive Radio." International journal of Communications, Network and System Sciences, 6, pp. 139-148, 2013.