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Spectrum Monitoring Using Fuzzy Logic for OFDM- Based Cognitive Radio Network

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Abstract**—**Spectrum sensing is a key function of cognitive radio network. This paper presents a spectrum monitoring algorithm according to fuzzy rules for Orthogonal Frequency Division Multiplexing (OFDM) based cognitive radios so that the primary user activity can be detected during the secondary user transmission. A Fuzzy based technique for primary user detection has also been proposed. In comparison with transmitter detection techniques Fuzzy based detection provides good results under low SNR values. This technique improve the jitter and throughput and also probability of false alarm and missed detection is improved.

Index Terms- Cognitive Radio, OFDM, Fuzzy rule, Energy detection, Spectrum sensing.

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I INTRODUCTION

The term "fuzzy logic" was introduced by Lotfi A. Zadeh, Professor while he taught in University of California at Beckley in 1965. Fuzzy logic has been utilized in many sectors like different domestic goods, microwave ovens, vacuum cleaners and other intelligent systems. Unlike ordinary binary system, the range of values would be in between 0 to 1. At present, wireless communication system has allocated and fixed frequency spectrum. And this is not accessible for unlicensed users. Even, this spectrum is not in use. Regulatory bodies in the world have been considering whether to allow unlicensed users in licensed bands if they would not cause any interference to licensed users. Due to above discussion, overall scope of research on cognitive radio in enhanced for dynamic spectrum access. Now days, static spectrum access is the main policy for wireless communications. Under this policy, fixed channels are assigned to licensed users or primary users (PUs) for exclusive use while unlicensed users or secondary users (SUs) are prohibited from accessing those channels even when they are unoccupied. The idea of a cognitive radio (CR) was proposed to achieve more efficient utilization of the RF spectrum[1]. One of

the main approaches utilized by cognitive networks is the overlay network model [2] in which SUs seek to opportunistically use the spectrum when the PUs are idle. Primary and secondary users are not allowed to operate simultaneously. In this method, secondary users must sense the spectrum to detect whether it is available or not prior to communication. If the PU is idle, the SU can then use the spectrum, but it must be able to detect very weak signals from the primary user by monitoring the shared band to quickly vacate the occupied spectrum. During this process, the CR system may spend a long time, known as the sensing interval, during which the secondary transmitters are silent while the frequency band is sensed. Since the CR users do not utilize the spectrum during the detection time, these periods are also called quiet periods (QPs) [3]. In the IEEE 802.22 system, a quiet period consists of a series of consecutive spectrum sensing intervals using energy detection to determine if the signal level is higher than a predefined value, which indicates a non-zero probability of primary user transmission. The energy detection is followed by feature detection to distinguish whether the source of energy is a primary user or noise [4],[5]. This mechanism is repeated periodically to monitor the spectrum. Once the PU is detected, the SU abandons the spectrum for a finite period and chooses another valid spectrum band in the spectrum pool for communication.

In many wireless systems and proven as a reliable and effective transmission method. For these reasons, OFDM is utilized as the physical layer modulation technique for many wireless systems including DVB-T/T2, LTE, IEEE 802.16d/e, and IEEE 802.11a/g. Similar to other wireless networks, OFDM is preferred for cognitive networks and has been already in use for the current cognitive standard IEEE 802.22. On the other hand, OFDM systems have their own challenges that need special treatment [10]. These challenges include its sensitivity to frequency errors and the large dynamic range of the time domain signal. Moreover, the finite time-window in the receiver DFT results in a spectral leakage from any in-band and narrow band signal onto all OFDM sub-carriers. When the secondary user utilizes OFDM as the physical transmission technique, a frequency domain based approach can be employed to monitor the spectrum during the CR reception only if the SU transmitter adds an additional feature to the ordinary OFDM signal. In this paper we optimize the performance of energy detection based spectrum sensing with the help of fuzzy rules to minimize the total error rate. Fuzzification optimization is achieved by minimising the error probability expressed in terms of missed detection and false alarm.

The paper is organised as follows. section II summarizes the system model. In section III matlab simulation is presented. Finally we draw conclusion in section IV .

II. SYSTEM MODEL

The secondary user physical layer model is designed to investigate and verify our spectrum monitoring algorithm. This model is very close to the OFDM system followed by [6]. At the transmitter side, data coming from the source is firstly segmented into blocks where each block is randomized, channel encoded, and interleaved separately. After interleaving, the data is modulated by the constellation mapper. The frequency domain OFDM frame is constructed by combining: (a) One or more training symbols or preambles that are used for both time and frequency synchronization at the receiver side. (b) The modulated data. (c) The BPSK modulated pilots which are used for data-aided synchronization algorithms employed by the receiver. Each *Ns* encoded complex data symbols generated by the frame builder are used to construct one OFDM symbol by employing the IDFT block that is used to synthesize the OFDM symbol, where *Ns* denotes the number of sub-carriers per one OFDM symbol. Thus, the *n*th time-domain sample of the *m*th symbol can be expressed as given by (1) where *C*(*k*,*m*) is the modulated data to be transmitted on the *m*th OFDM symbol with the *k*th sub-carrier.

$$S(n,m)=\frac{1}{\sqrt{Ns}}\sum_{k=-\frac{Ns}{2}}^{\frac{Ns}{2}-1} C(k,m)\, e^{\frac{j2\pi kn}{Ns}} \qquad (1)$$

detection, start of symbol timing, and SFO estimation and compensation) and frequency synchronization (CFO estimation and correction), the cyclic prefix is removed. Then, the received OFDM symbol is transformed again into the frequency domain through an *Ns* point DFT. The channel is then estimated and the received data is equalized. The complex data output is then mapped to bits again through the De-mapper. De-interleaving, decoding, and De-randomization are applied later to the received block to recover the original source bits.

The essence of spectrum sensing is a binary hypothesis-testing problem:

$H0$: primary user is absent;

$H1$: primary user is in operation.

The cognitive radio spectrum sensing is a binary hypothesis testing problem and can be formulated as follows.

$$y(n) = \begin{cases} w(n) & ;H0 \\ s(n)+w(n) & ;H1 \end{cases}$$

where n=1,2,.....N

where hypothesis $H0$ denotes the absence of the primary user and hypothesis $H1$ denotes the presence of the primary user. $y(n)$ is the signal received at the secondary receiver, $w(n)$ is the AWGN of variance σ_w^2 and $s(n)$ is the primary user signal assumed to be real Gaussian with variance σ_s^2. Moreover, $s(n)$ and $w(n)$ are assumed to be independent and the noise power is known a priori. With the energy detector, the average probability of false alarm, the average probability of detection, and the average probability of missed detection over AWGN channels are given, respectively, by [7]

$$P_f = \Gamma(m,\tfrac{\lambda}{2})/\Gamma(m) \qquad (2)$$

$$P_d = Q_u(\sqrt{2\gamma},\sqrt{\lambda}) \qquad (3)$$

and

$$P_m = 1 - P_d \qquad (4)$$

III MATLAB SIMULATION

In this paper, we have two inputs and one output fuzzy logic MATLAB tool. Fuzzy logic technique is used to analyse nonlinear systems. It deals with those systems which are difficult to resolve using conventional mathematical models. For designing, we utilize mamdani model in fuzzy logic tool to control different parameters of cognitive radio. We have primary and secondary users as inputs and channel modelling at the output.For simulation MATLAB R2012 platform is used.

This section offers the proposed work and algorithm to triumph over all related issues which has certain in earlier sections. The scheduler uses the fuzzy logic to obtain all desires. The benefit of using fuzzy common sense is that it is able to be designed for complex problems with most effective logical rules therefore does not require complex mathematical calculation. The proposed algorithm can be written as follows:

set of rules:
start:
1. Feel available Bandwidth (BW);
2. Feel traffic Load within the community;
3. From the input queue test the requested statistics to be transmitted
4. Check their precedence, facts length and BW-requirement;
5. Apply fuzzy rule for each entry;
6. Serve the request in keeping with fuzzy output;
7. Stop.

Quit
Fuzzy common sense Scheduler: utilized in step five of predominant set of rules
start:
1. Practice fuzzy logic with precedence, statistics size and BW-required in the following way.
a.) A fuzzy rule within the form “If…. Then”;
b.)Locate membership feature;
c.) Hold fuzzy table from fuzzy matrix;
2. Repeat the procedure for all entries.
3) go to step (6) of foremost set of rules;
stop

The begin is the rounded rectangle field which initializes the bushy Controller via loading the pre-described rules. next container is to examine the enter queue to check the requests in waiting situations. The in line with requests type the price of priority, facts length of request and the required BW is envisioned. After that the channel and community condition is analyzed. Now the fuzzy policies are applied to every access.

After finishing this section offer the transmission priority to each request according to fuzzy output.

MATLAB Simulation results are shown in following figures. Figure 1 showas that total error rate in terms of the detection threshold from n =1 to n = 10 in a cognitive network with 10 users. It can be observed from Fig.1 that the all the examined range of detection thresholds is n = 5. However, for a fixed very small threshold n = 10. Meanwhile, for a fixed very large threshold n = 1, tends to be optimal.

Fig.2 illustrate the bit error rate of received symbols i.e. bit error rate verses signal to noise ratio (SNR) is plotted at bandwidth BW=2MHz for OFDM system. In this plot binary shift keying modulation (BPSK) technique is used.

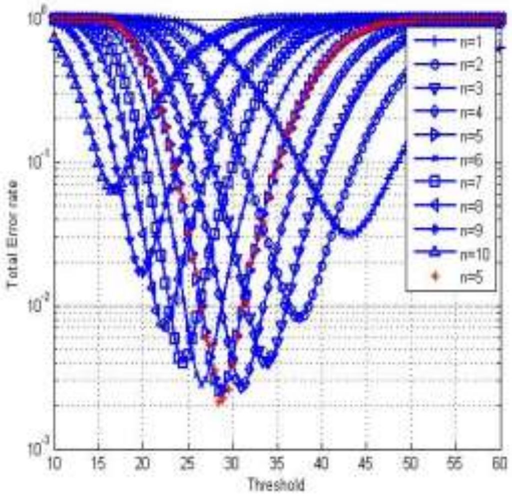

Fig.1 total error rate in terms of detection threshold of spectrum sensing in AWGN channel.

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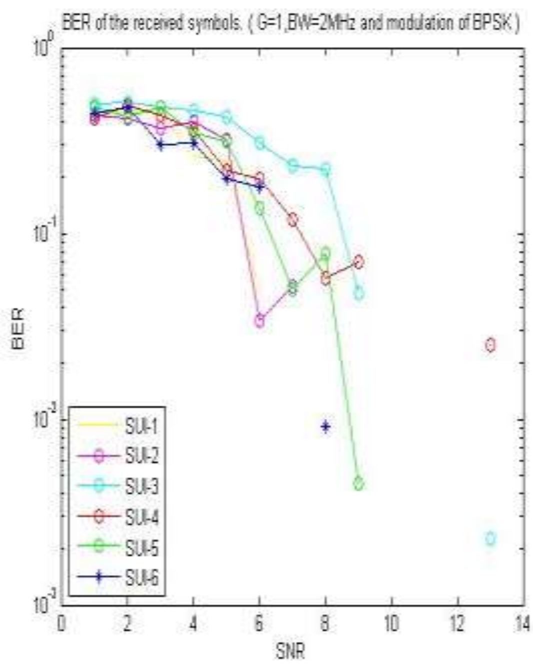

Fig.2 bit error rate of received symbols at G=1, BW=2MHz and modulation of BPSK.

Fig.3 shows the plot for signal to noise ratio(SNR) verses mean square error(MSE) for an OFDM system.This plot implies the SNR degradation. This Fig. shows the advantages of the powerful estimation techniques we have chosen for the OFDM.

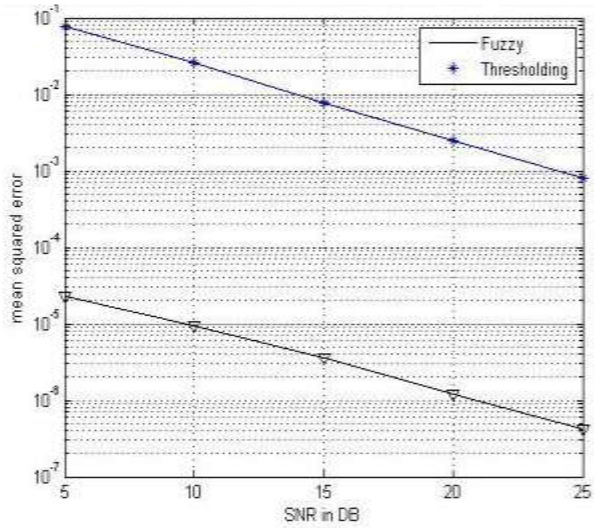

Fig.3 simulation result for mean square error

Fig.4 illustrates the ROC (Receiver Operating Characteristics) curves i.e. versus using fuzzy logic for spectrum sensing. The graph is plotted for Rayleigh channel and it shows that with the help of fuzzy logic, the probability of detection increases.

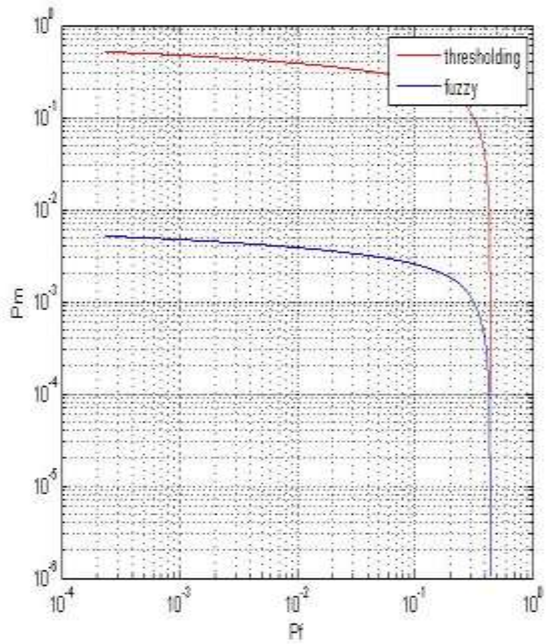

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Fig4. Spectrum sensing performance

The detection probability for fuzzy logic is simulated in the presence of power leakage. With our technique the detection performance is better than the previous technique as shown in fig.5

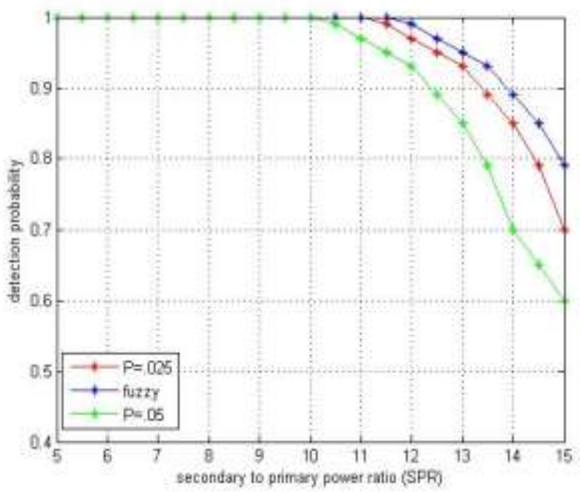

Fig.5 simulation result for detection probability

IV CONCLUSION

In this paper, spectrum monitoring algorithm according to fuzzy rules for Orthogonal Frequency Division multiplexing to optimize the detection performance in an efficient and implementable way. In comparison with transmitter detection techniques Fuzzy based detection provides good results under low SNR values. Our proposed algorithm can greatly enhance the performance of OFDM-based cognitive networks by improving the detection performance with a very limited reduction in the secondary network throughput and with increase in SNR (Signal to Noise Ratio), the probability of detection increases by improving the probability of false alarm and missed detection is improved.

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