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Investigate the Performance of Spectrum Sensing Cognitive Radio Users through Energy Detection

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Abstract:

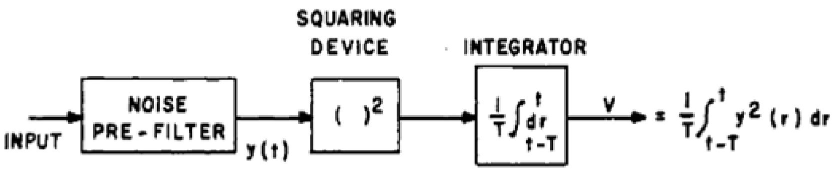
With the development of a new and ever expanding wireless applications and services, spectrum resources are facing in demands. In present scenario, the spectrum allotment has been done by providing each new service with its own fixed frequency Slot. Most of the user's spectrum is already assigned, so it becomes very difficult to find spectrum for other users or existing users. This leads to the scarcity of available spectrum and inefficient channel utilization. Cognitive radio is a novel technology which improves the spectrum utilization by allowing secondary user to borrow unused radio spectrum from primary licensed users or to share the spectrum with the primary users. Present paper deals with the spectrum sensing in which multiple users detect the spectrum gap through energy detection and investigate the detection performance in an efficient and implementable way. Simulation results showed that the probability of detection increases significantly when SNR increases in cognitive environment.

Keywords: FCC, TRAI, ISM, LRT

I. INTRODUCTION

The radio spectrum is limited resource and is regulated by government agencies such as telecom Regulation Authority of India (TRAI) in India, Federal Communication Commission (FCC) in the United States. Demand for wireless services requires the use of more spectrum resources. However, today's wireless networks are characterized by a fixed spectrum assignment policy. As a result, few spectrum resources such as 2.4 GHz unlicensed industrial, scientific, and medical (ISM) band are currently available for future wireless applications [1]. Operating in unlicensed band leads to create interference between systems users degrades the system performance. To make the intelligent wireless communication system, cognitive radio is aware of the radio frequency environment, selects the communication parameters (such as carrier frequency, modulation type, bandwidth and transmission power) to optimize the spectrum usage and adapts is transmission and reception accordingly [2]. By sensing and adapting to the environment, a cognitive radio is able to allot in the spectrum and serve its user without causing interference to the licensed user. To do so, the cognitive radio must continuously sense the spectrum it is using in order to detect the re-appearance of the primary user. Once the primary is detected the cognitive radio should withdraw from the spectrum instantly so as to minimize the interference. This is very difficult task as the various primary users will be employed different modulation schemes, data rates and transmission powers in the presences of variable propagation environment and interference generated by other secondary users [3]
In general, spectrum sensing techniques can be classified into three categories; energy detection, matched filter coherent detection, and cyclostationary feature detection [4]. These spectrum techniques are widely used techniques as detection techniques. Among them, energy detection has been widely applied since it does not require any a priori knowledge of the primary signals and has much lower complexity than the other two schemes. In addition, it does not need any prior information about the PUs' signals. Therefore, it has been thoroughly studied both in local spectrum sensing [5]. In this paper we studied energy detection technique to view its performance in sensing.

II. SYSTEM MODEL



In CR network *K* number of secondary users and primary users are considered with common receiver, as shown in Fig. 1[5]. It is assumed that each secondary user sensing the spectrum independently and then the local decisions are sent to the common receiver which can combine all the available decision to conclude the absence or presence of the primary users (PU). The essence of spectrum sensing is a binary hypothesis-testing problem. Consider there are M >1number of antennas are present at the receiver. In the Eqn 3 the spectrum sensing at CR *i* is considered [6]. The sensing method is to decide between the following two hypotheses,
$X(t) = [X_1(t) \ldots\ldots X_M(t)]^T$;
$S(t) = [S_1(t) \ldots\ldots S_M(t)]^T$;

$n(k) = [n1(t) : : : n_M(t)]^T$:
$\boldsymbol{H_0}$ **:** Absent the Primary user
$\boldsymbol{H_1}$: Present the Primary user

$$(X_i t) = \begin{cases} (t), & H_0 \\ h(t)s(t) + n_i(t), & H_1 \end{cases} \quad \ldots(1)$$

where $X_i(t)$ is the received signal at the i_{th} CR in time slot t, $s(t)$ is the primary user signal, $n_i(t)$ is the additive white Gaussian noise (AWGN), and $h_i(t)$ denotes the complex channel gain of the sensing channel between the PU and the i_{th} CR. For a given probability of false alarm P_{fa}, i.e. the probability of mistaking the presence of the primary signal when it actually not present. The system model is to choose the hypothesis for maximizes the probability of detection Pd, i.e. the probability of correctly determining the presence of the primary signal, for a given number of samples. In the description that follows, following [5-6] it would be shown that the optimal receiver derived from Neyman-Pearson theorem reduces to many known estimators. Special emphasis will be given to a few latest techniques in cooperative sensing, and one blind sensing algorithm will also be evaluated. For a given P_{fa}, the Neyman-Pearson theorem states that P_d will be maximized for the following decision statistic, which is essentially the likelihood ratio test (LRT):

$$T_{LRT}(x) = \frac{p(X/H_1)}{p(X/H_0)} \ldots(2)$$

Where X is the aggregation of X(t); t = 0……….N -1 [7]. The model assumes that the distributions of signal and noise are known, which hardly the case is. Under the assumption that we are dealing with a flat fading channel, and the $s_i(k)$'s are independent over k, we have the following PDFs

$$P\big((X\,|Hi)\big) = \prod_{k=0}^{N-1} p(X(k)|Hi) \ \ldots(3)$$

Assuming Gaussian distributions for noise and signal samples, i.e $.n(k)\sim N(0,\sigma_n^2 I)$, and $s(k)\sim N(0,R_n)$ the LRT reduces to estimator-correlator (EC) detector

$$T_{EC}(x) = \sum_{k=0}^{N-1} x^T(k) R_s (R_s + \sigma_n^2 I)^{-1} x(k)$$

It can further be noticed that $R_s(R_s + \sigma_n^2 I)^{-1}x(k)$ is the MMSE estimation of s(k), so that TEC is actually the correlation of the observed signal x(k) with MMSE estimation of s(k). The assumption that $R_s = \sigma_s^2 I$reduces T_{EC} to the energy-detector (ED) given by

$$T_{ED}(x) = \sum_{k=0}^{N=1} x^T(k) x(k)$$

Furthermore, under the assumption that s(k) is deterministic and known to the receiver, LRT reduces to the matched-filter detector given by

$$T_{MF}(x) = \sum_{k=0}^{N-1} S^T(k) x(k)$$

So, we notice that the LRT reduces to different known detectors under given constraints

If prior knowledge of the PU signal is unknown, the energy detection method is optimal for detecting zero-mean constellation signals [7-8]. For the i_{th} CR 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 [11]

$$P_{f,i} = \frac{\Gamma\left(u,\frac{\lambda i}{2}\right)}{\Gamma(u)} \ \ldots(4)$$

$$P_{d,i} = Q_u(\sqrt{2\gamma i}, \sqrt{\lambda i}) \ldots(5)$$

$$P_{m,i} = 1 - P_{d,i} \quad \ldots(6)$$

In the above equations, λi and γi denote the energy detection threshold and the instantaneous signal-to-noise ratio (SNR) at the i_{th} CR, respectively, u is the time-bandwidth product of the energy detector.

$$\Gamma(a,x) = \int_x^\infty t^{\alpha-1} e^{-t} dt$$

$\Gamma(a,x)$ is the incomplete gamma function**.** $(a,\ )$ is the generalized Marcum Q function [9-10,12].

III. SIMULATION RESULT AND DISCUSSION

The Simulation has been carried out for cognitive radio network on MATLAB under AWGN channel. Under this simulation five primary users and secondary users in the spectrum have been considered. The performance has been detected with the probability of detection, false alarm probability and missed probability under different number of SNR. The Energy detection is used to detect the vacant spectrum in cognitive radio network, where primary users are not present. Immediately assigned this vacant spectrum to secondary users and whenever primary user want to occupy the spectrum, secondary user immediately left this vacant spectrum. The carrier frequencies 1000 Hz to 5000 Hz for five users are used and sampling frequency is 12000 Hz. The Power spectrum density of signals are calculated and compared with the threshold value to determine the availability of primary users. Fig.1 shows that Probability of detection in spectrum sensing for different SNR under AWGN channel. The simulation was carried out for the analysis of detection probability under different number of SNR. Where Pfa=0.01 and time bandwidth factor u=100 were taken for this simulation. SNR was taken -20dB to10dB. It also shows that with the increasing of the SNR (from -13dB to -3dB) the detection also increased and detection probability was almost constant or 1 after -3dB to 10 dB. Fig. 2 shows that performance of missed detection varies based on SNR. It has been found that missed probability detection decreases from 0.7 to zero as SNR is varies from -20dB to -3dB and than it is constant. In present result the odd primary users are present and at even numbers the slot are vacant. In spectrum sensing, it is desired to minimize spectrum sensing error (i.e., sum of false alarm and miss detection probabilities) since minimizing spectrum sensing error both reduces collision probability with primary user and enhances usage level of vacant spectrum. To provide reliable spectrum sensing performance (i.e., minimize spectrum sensing error), one of the great challenges is determining threshold level since spectrum sensing performance depends on the threshold level. When determining threshold level, besides spectrum sensing error, spectrum sensing constraint which requires false alarm and miss detection probabilities to be below target level should also be considered since it guarantees minimum required protection level of primary user and usage level of vacant spectrum.

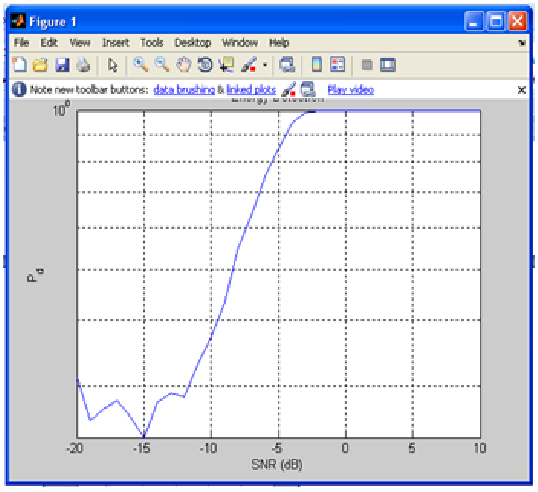


Figure 1: Probability of detection of Five Primary users with single secondary user

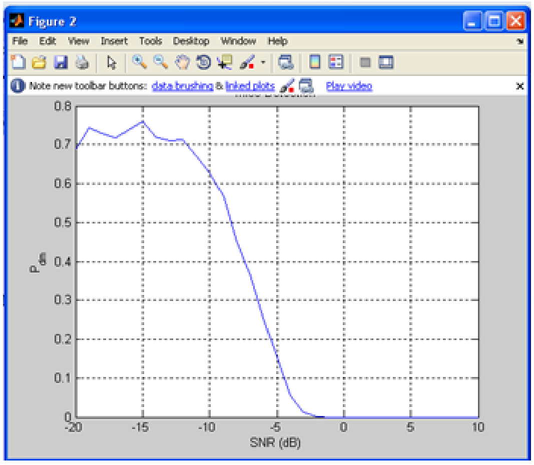


Figure 2: Probability of missed detection of three primary users with single secondary user

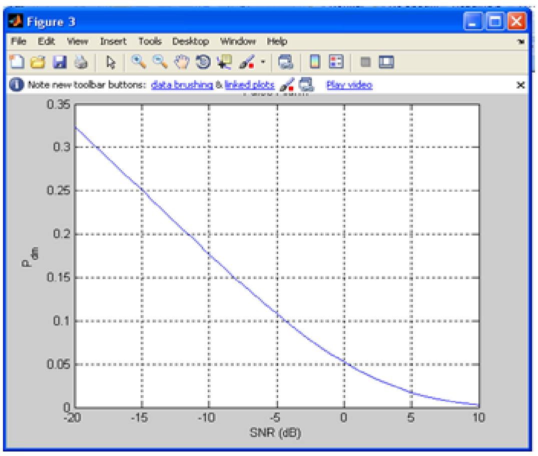


Figure 3: Probability of false detection of three primary users with single secondary user

IV. CONCLUSIONS

In this paper, we built the cognitive radio environment for five primary users along with secondary users. The performance has been investigated in terms of probability of detection and Missed detection and false probability in spectrum sensing technique. The measured detection is compared with the threshold value using energy detection and result showed the minimize the spectrum sensing error for a given inequality spectrum sensing constraint. It can be seen from figure 1 that primary signals have been generated successfully. It can be seen from figure 2 that energy calculation and detection of generated primary user signal have been done & empty slots have been found successfully. It can be seen from figure 3 that secondary user signals have been generated on allocated vacant slots with priority consideration.

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