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Spectrum sensing Techniques In Cognitive Radio

Neeraj Bansal[*1], Pravin Patidar[2], Dr.S.J. Basha[3]
[*1,2,3]LNCT, Indore, India
n7.bansal@gmail.com

Abstract

The growing insist of wireless applications has put a lot of constraint on the usage of available radio spectrum which is limited and valuable resource. However, a fixed spectrum assignment has lead to under utilization of spectrum as a great segment of licensed spectrum is not effectively utilized. Cognitive radio is a promising technology which provides a novel way to improve utilization efficiency of available electromagnetic spectrum. Spectrum sensing helps to detect the spectrum holes (underutilized bands of the spectrum) providing high spectral resolution capability. In this paper, analysis of spectrum sensing techniques is obtainable. The challenges and issues concerned in implementation of spectrum sensing techniques are discussed in detail giving comparative study of diverse methodologies.

Keywords - Cognitive Radio, Dynamic Spectrum Access, Spectrum Sensing Methods

Introduction

The available electromagnetic radio spectrum is a limited natural resource and getting crowded day by day due to increase in wireless devices and applications[1]. It has been also found that the allocated spectrum is underutilized because of the static allocation of the spectrum. Also, the conventional approach to spectrum management is very inflexible in the sense that each wireless operator is assigned an exclusive license to operate in a certain frequency band. And, with most of the useful radio spectrum already allocated, it is difficult to find vacant bands to either deploy new services or to enhance existing ones. In order to overcome this situation, we need to come up with a means for improved utilization of the spectrum creating opportunities for dynamic spectrum access. The issue of spectrum underutilization in wireless communication can be solved in a better way using Cognitive radio(CR)technology [2]. Cognitive radios are designed in order to provide highly reliable communication for all users of the network, wherever and whenever needed and to facilitate effective utilization of the radio spectrum. Fig. 1.1 and show relatively lowutilization of the licensed spectrum which is largely due to inefficient fixed frequency allocations rather than any physical shortage of spectrum. This observation has forced the regulatory bodies to search a method where secondary (unlicensed) systems are allowed to opportunistically utilize the unused primary (licensed) bands commonly referred to as white spaces. Cognitive radio can change its transmitter parameters based on interaction with environment in which it operates. Cognitive radio includes four main functional blocks: spectrum sensing, spectrum management, spectrum sharing and spectrum mobility. Spectrum sensing aims to determine spectrum availability and the presence of the licensed users (also known as primary users). Spectrum management is to predict how long the spectrum holes are likely to remain available for use to the unlicensed users (also called cognitive radio users or secondary users). Spectrum sharing is to distribute the spectrum holes fairly among the secondary users bearing in mind usage cost. Spectrum mobility is to maintain seamless communication requirements during the transition to better spectrum. Among all other functions, Spectrum sensing is believed as the most crucial task to establish cognitive radio networks. The various spectrum sensing techniques includes primary transmitter detection, cooperative detection and interference detection. These are discussed and compared in detail in upcoming section

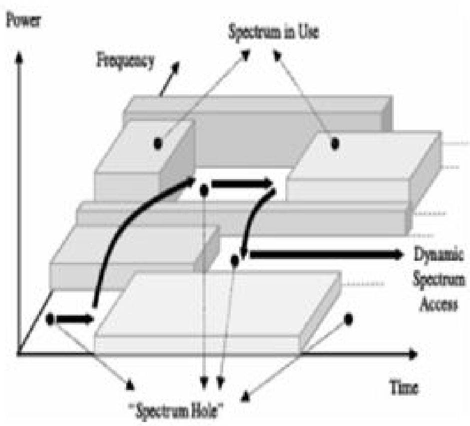

Figure 1 Illustration of spectrum white space

Spectrum Sensing

A major challenge in cognitive radio is that the secondary users need to detect the presence of primary users in a licensed spectrum and quit the frequency band as quickly as possible if the corresponding primary radio emerges in order to avoid interference to primary user[3]. This technique is called spectrum sensing. Spectrum sensing and estimation is the first step to implement Cognitive Radio system We can categorize spectrum sensing techniques into direct method, which is considered as frequency domain approach, where the estimation is carried out directly from signal and indirect method, which is known as time domain approach, where the estimation is performed using autocorrelation of the signal. Another way of categorizing the spectrum sensing and estimation methods is by making group into model based parametric method and periodogram based non-parametricmethod.

Spectrum Sensing Techniques

Primary transmitter detection: In this case, the detection of primary users is performed based on the received signal at CR user[3]. This approach includes matched filter (MF) based detection, energy based detection, covariance based detection, waveform based detection, cyclostationary based detection, radio identification based detection and random.

A.ENERGY BASED DETECTION

It is a non-coherent detection method that detects the primary signal based on the sensed energy [4]. Due to its simplicity and no requirement on a priori knowledge of primary user signal, energy detection (ED) is the most popular sensing technique in cooperative sensing.

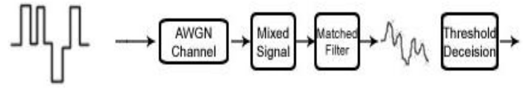

Fig 2 Energy detector block diagram

The block diagram for the energy detection technique is shown in the Fig 1 In this method, signal is passed through band pass filter of the bandwidth W and is integrated over time interval. The output from the integrator block is then compared to a predefined threshold. This comparison is used to discover the existence of absence of the primary user. The threshold value can set to be fixed or variable based on the channel conditions. The ED is said to be the Blind signal detector because it ignores the structure of the signal. It estimates the presence of the signal by comparing the energy received with a known threshold derived from the statistics of the noise. Analytically, signal detection can be reduced to a simple identification problem, formalized as a hypothesis test.

B.MATCHED FILTER DETECTION

A matched filter (MF) is a linear filter designed to maximize the output signal to noise ratio for a given input signal[5]. When secondary user has a priori knowledge of primary user signal, matched filter detection is applied. Matched filter operation is equivalent to correlation in which the unknown signal is convolved with the filter.

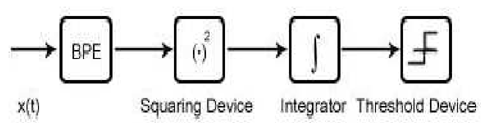

Fig.3Matched filter block diagram

Where 'x' is the unknown signal (vector) and is convolved with the 'h', the impulse response of matched filter that is matched to the reference signal for maximizing the SNR. Detection by using matched filter is useful only in cases where the information from the primary users is known to the cognitive users.

C.CYCLOSTATIONARY BASED DETECTION

It exploits the periodicity in the received primary signal to identify the presence of primary user(PU)[5]. The periodicity is commonly embedded in sinusoidal carriers, pulse trains, spreading code, hopping sequences or cyclic prefixes of the primary signals. Due to the periodicity, these cyclostationary signals exhibit the features of periodic statistics and spectral correlation, which is not found in stationary noise and interference .Thus, cyclostationary feature detection is robust to noise uncertainties and performs better than energy detection in low SNR regions.

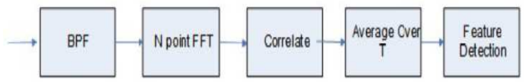

Fig. 4 Block Diagram of Cyclostationary based Detection

Although it requires a priori knowledge of the signal characteristics, cyclostationary feature detection is capable of distinguishing the CR transmissions from various types of PU signals. This eliminates the synchronization requirement of energy detection in cooperative sensing. Moreover, CR users may not be required to keep silent during cooperative sensing and thus improving the overall CR throughput. This method has its own shortcomings owing to its high computational complexity and long sensing time. Due to these issues, this detection method is less common than energy detection in cooperative sensing. The comparison of different transmitter detection techniques for spectrum sensing and the spectrum opportunities is shown in figure. As it is evident from the figure, that matched filter based detection is complex to implement in CRs, but has highest accuracy.

System Model And Notations

Here we describing the system model, we first list the entire notation used for results.

$s(t)$: - Signal Waveform

$n(t)$: - Noise waveform which is modeled as a Zero mean white Gaussian random process

N_{01} : - One sided noise power spectral density

$N_{02} = \frac{N_{01}}{2}$: - Two sided noise power spectral density.

E_s : - Signalenergy $= \int_0^t S^2(t)dt$

γ: - Signal to noise ratio (SNR)

λ : - Energy threshold used by the energy detector

T : - Observation time interval in seconds

W:-One sided bandwidth (Hz) i.e. positive bandwidth of the low pass filter

$u = TW$: - Time Bandwidth product.

f_c : - carrierfrequency.

P_d: -Probability of detection.

P_f: - Probability offalsealarm.

P_m: -1$-P_d$Probabilityofmiss detection.

H_0 : - Null hypothesiscorresponding to no signal transmitted.

H_1: -True hypothesiscorresponding to signal transmitted by the source.

$N(\mu, \sigma^2)$: - A Gaussian va riate with mean μ and variance σ^2.

$x_\alpha{}^2$: -A central chi-square variety with α degrees of freedom

$x_\alpha{}^2(\beta)$: -A non-centrallychi-squarevariatewithα degrees offreedomandn on-centrality parameter β.

$$y(t) = h * s(t) + n(t) \quad (1)$$

Where $h = 0$ or 1 under Hypotheses H_0 or H_1 respectively as described in the paper [4], the received signal is first pre filtered by an ideal band pass filter with transfer function.

$$H(f) = \begin{cases} \frac{2}{\sqrt{N_{01}}}, & |f - fc| \le W \\ 0\,, & |f - fc| > W \end{cases} \quad (2)$$

To limit the average noise power and normalize thenoisevariance.Theoutputofthisfilteristhensquaredandintegratedoveratimeinterval$T$tofinallyproduceameasureofthe energy of the received wave form. The output of the integrator denoted by Y will act as the test statistic to test the two hypothesesH_0 and H_1 .Although this process is of band-pass type, one can still deal with it slow-pass equivalent form and eventually translate it back to its band-pass type[6]

According to the sampling theorem, the noise process can be expressed as

$$n(t) = \sum_{i=-\infty}^{\infty} n_i \, sinc(2Wt - i) \quad (3)$$

$$\text{Where} n_i = n\left(\frac{i}{2W}\right),$$

$$\text{sinc(x)} = \frac{\sin(\pi x)}{\pi x} \quad (4)$$

$$n_i \sim N(0, N_{01}W) \ \text{ for all value of } i$$

Over the interval (0, *T*), noise energy can be approximated as [15]

$$E_n(Energy\ of\ noise\ signal) = \int_0^T n^2(t)\, dt \quad (5)$$

Now in order to make noise variance equal to 1 or normalization condition we can divide the noise sample by the square-root of its variance i.e.

$$n_i' = (\frac{n_i}{\sqrt{N_{01}W)}} \quad (6)$$

Then the test or decision statistics Y can be expressed as [4]

$$Y = \sum_{i=1}^{2u} n_i'^2 \quad (7)$$

In this section we analyse the probability of detection P_d and probability of false alarm P_f over AWGN channel [7].

$$P_f = Prob(H_1/H_0) = Prob(Y > \lambda/H_1)$$

$$P_f = \frac{\Gamma\left(u, \frac{\lambda}{2}\right)}{\Gamma(u)} \quad (8)$$

Probability of detection can be evaluate from (3.25) is expressed as

$$P_d = Prob(H_1/H_1) = Prob(Y > \lambda/H_1)$$

$$P_d = Q_u\left(\sqrt{2\gamma}, \sqrt{\lambda}\right) \quad (9)$$

Results And Discussion

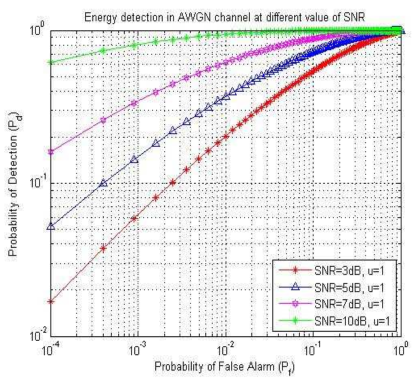

Fig5Energydetection in AWGN channel at different value of SNR and constant value of u=1

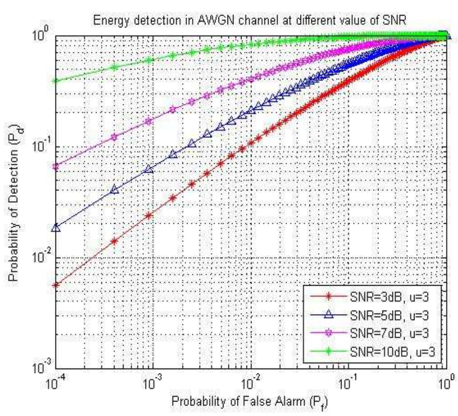

Figure6 Energy detection in AWGN channel at different value of SNR and constant value of u=3

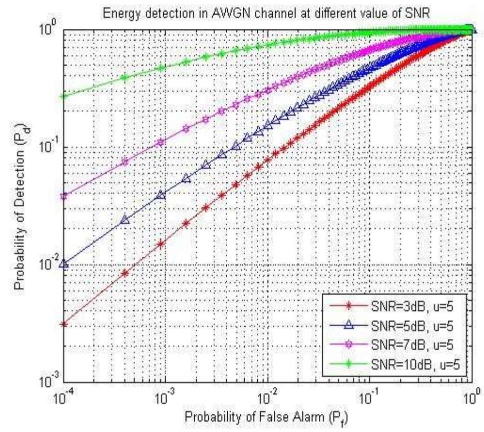

Fig 7Energydetection in AWGN channel at different value of SNR and constant value of u=5

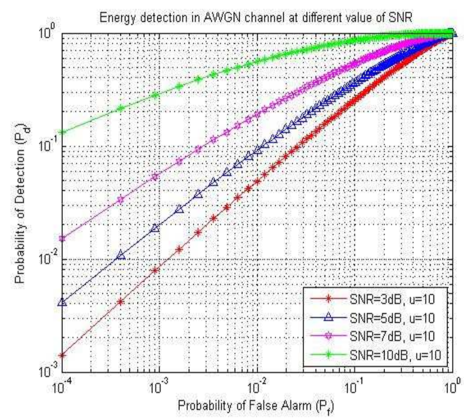

Fig8Energy detection in AWGN channel at different value of SNR and constant value of u=10

The figure(4to8)shows, the receiver operating characteristics (ROC), ($P_d$versusP_f) curves in AWGN channel for different values of SNR(SNR=3dB,SNR=5dB,SNR=7dB,SNR=10dB) with the constant value of (1,3,5,10) respectively. So by the analysis of figures, its clears that as we increases the value of from the previous figure it will gives the lower probability of detection P_d.

Conclusion

As the demand of radio spectrum increases in past few years and licensed bands are used inefficiently, improvement in the existing spectrum access policy is expected. Dynamic spectrum access is imagine to resolve the spectrum shortage by allowing unlicensed users to dynamically utilize spectrum holes across the licensed spectrum on no interfering basis.

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