



Spectrum Sensing Techniques under Different Wireless Channels

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Abstract— *The rapid growth of wireless communication has made the problem of under utilization of bandwidth scarcity has become more popular. Cognitive radio technology has come out to solve this problem by allowing unlicensed user to use licensed spectrum bands opportunistically without affecting their performances. Spectrum sensing is one of the most challenging issues in cognitive radio system. Result it has gained more attention by the researchers in this field. This paper presents a comprehensive performance of spectrum sensing techniques and their performance on different wireless channels (AWGN and RAYLEIGH). Multiple aspects of spectrum sensing problem are studied from a wireless channel point of view.*

Keywords - *Cognitive Radio, Energy Detection, Matched Filter Detection, Cyclostationary Detection , Wireless Channels.*

I. INTRODUCTION

With the ever rising wireless communication, setbacks like bandwidth scarcity have gained more attention. While, the recent studies by FCC have shown that huge portion of spectrum is vacant most of the time. This portion is the licensed spectrum band which can only be utilized by licensed users only. Hence, to resolve this problem of under-utilized spectrum, secondary users are permitted by the FCC to utilize the licensed band when it is not in use and named it as cognitive radio. Spectrum sensing is used to sense the presence of licensed users .Energy Detection, Matched Filter detection and Cyclostationary detection are the three standard methods used for spectrum sensing. All these three techniques have been explained further. Section 2explains the various wireless channels; section 3 throws light on the spectrum sensing definition and various probabilities that help us realize the results. Section 4 explains the energy detection spectrum sensing the Section 5 shows the simulation results while Section 6 concludes the paper.

II. WIRELESS CHANNELS

Wireless channels provide the physical means to transport a signal produced by the transmitter and delivers it to the receiver. Behaviors of a wireless communication channel vary with time. On the other hand, models used to describe the behavior of wireless links are not precise; they may offer a rough calculation. To portray wireless channel behavior various models are available, such as an AWGN (Additive White Gaussian Noise) model and fading model like Rayleigh model.

AWGN Channel

A straight forward environment for a wireless communication system to operate is the AWGN environment. Due to the channel effect, the transmitted channel is summated with a random signal. Henceforth, the received signal $s(t)$, can be expressed as

$$s(t) = x(t) + n(t) \dots\dots\dots(1)$$

Where, $x(t)$ is the transmitted signal, and $n(t)$ is the background signal.

Rayleigh Fading Channel

A communication channel that faces different fading phenomenon during signal transmission is called a fading channel. Multipath propagation is the major cause of fading. The signal that arrives at the receiver comes from different paths having different delays and path gains. These propagations paths might seem to be destructive or constructive. Finally the received signal is the algebraic sum of various paths of propagation so that some of the paths are added and the other are subtracted. Primary reason for Rayleigh fading is the multipath reception of the transmitted signal. There is no direct line of sight between the receiver and the transmitter. Consider a transmitted signal, $x(t)$,

$$x(t) = \cos(wc t) \dots\dots\dots(2)$$

Where, wc is the transmitted signal frequency in radian/sec, hence, received signal, $s(t)$, can be expressed as-

$$s(t) = \sum a_i \cos(Wct + \phi_i) \dots\dots\dots (3)$$

where, N is the number of paths, ϕ_i is the phase shift of each path, that depends on delay difference and takes values 0 to 2π , and a_i is the amplitude of each path i .

III. SPECTRUM SENSING

The task of sensing the radio spectrum in its local neighborhoods of the cognitive radio, to find the spectrum holes is defined as spectrum sensing. Due to various reasons spectrum sensing is considered as the most essential function of the cognitive radio.

Basic duty of spectrum sensing is to identify the spectrum white spaces i.e. spectrums which are currently unused by the primary users. Then it can broadcast in these spaces in a way that no interference is caused to the primary users. Another motive of cognitive radio to sense the wireless medium is to sense if any other secondary device is transmitting. Here, the cognitive radio needs to share either some or all the channels occupied by other secondary devices with the object of reducing its own blocking probability. Spectrum sensing problem can be put together as a binary hypothesis testing, with two hypotheses

$$H_0: y[n] = w[n]; n= 1, 2... N$$

$$H_1: y[n] = x[n] + w[n]; n= 1, 2... N$$

Where, H_0 states that received signal samples $y[n]$ correspond to noise sample signal $w[n]$ and hence, primary signal is not sensed to be present in the spectrum band. H_1 indicates the presence of some primary users signal $x[n]$. N denotes the number of samples gathered during sensing period. Ideally the spectrum sensor would select H_1 to show the presence of primary users and H_0 otherwise. In practice spectrum sensing algorithms fall into mistakes, which are classified as missed detection and false-alarm, which may be defined as-

Probability of Missed detection, P_{md} .

The condition when a primary user is detected to be absent while it is actually present, is called the probability of missed detection. Higher value of P_{MD} leads to higher interference because in this case the secondary user will assume that the spectrum is free while the spectrum is actually utilized by the primary users.

$$P_{md} = P(H_0/H_1) \dots\dots\dots (4)$$

Probability of detection, P_d

The probability of detection is the condition when the primary users are detected to be present while they are actually present, higher value of P_D avoids any interference from the secondary users if they are trying to access the spectrum. A high value of P_D will lead to efficient use of the spectrum without causing interference to the primary user.

$$P_d = P(H_1/H_1) \dots\dots\dots (5), \text{ or}$$

$$P_d = 1 - P_{md} \dots\dots\dots (6)$$

Probability of False alarm, P_{fa}

It is defined as the probability of detecting that primary user is present while it is actually absent, and this leads to inefficient utilization of the spectrum. Because, even if the spectrum is free, the secondary user will assume that it is occupied by the primary user and hence will not be able to utilize the spectrum. A low value of P_{FA} is expected to increase the channel reuse capability when it is free (5).

$$P_{fa} = P(H_1/H_0) \dots\dots\dots (7)$$

IV. SPECTRUM SENSING TECHNIQUES

Energy Spectrum Detection

Energy detector based technique also known as periodogram, is the most commonly used technique for the purpose of spectrum sensing due to its low implementation and computational complexities. The benefit is that it does not need any information about the primary user signal, hence when the receiver is unable to gather enough information about the primary signal then this technique is the most appropriate to use. To determine the energy of the received signal, output signal from band-pass filter with bandwidth W is squared and integrated over the observation interval T . Now finally, Y , the output of the integrator is compared with a threshold γ to decide if a licensed user is present or not. Only shortcoming of this method is the increased sensing time. Major challenges of energy detector based sensing are the selection of threshold to detect the primary users, the inability to differentiate whether the interference being caused is from primary users or noise, and its poor performance when the Signal-to-Noise ratio is low. Hence, energy detector is considered to be optimal when the cognitive devices have no prior information about the features of primary signals except local noise statistics. Output of the integrator is the energy of the filtered received signal over the time interval T and this output is considered the test statistic to test the two Hypotheses H_0 and H_1 .

H_0 : corresponds to the absence of the signal and only presence of noise.

H_1 : corresponds to the presence of both signal and noise.

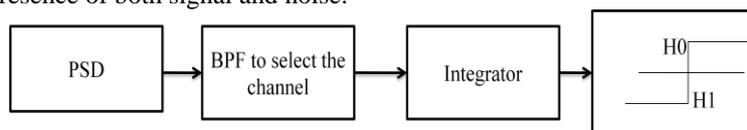


Figure 1, shows the block diagram of energy detector.

Matched Filter Spectrum Detection

A matched filter (MF) is a linear filter designed to maximize the output signal to noise ratio for a given input signal. 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 whose impulse response is the mirror and time shifted version of a reference signal. The operation of matched filter detection is expressed as:

∞

$$Y[n] = \sum_{k=-\infty}^{\infty} h[n-k]x[k] \dots \dots \dots (3)$$

$k=-\infty$

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.

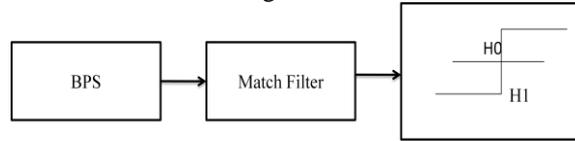


Fig. 2: Block diagram of matched Filter detection.

Cyclostationary feature Spectrum Detection

It exploits the periodicity in the received primary signal to identify the presence of primary users (PU). 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. 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.

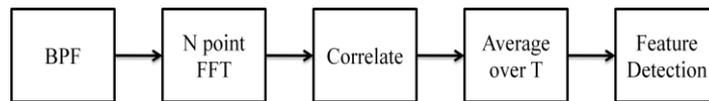


Fig. 3: Block diagram of Cyclostationary feature detection.

V. SIMULATION AND RESULTS

In this paper, spectrum sensing techniques is simulated over several wireless channels using MATLAB. The simulation shows spectrum sensing techniques in AWGN channel and Rayleigh fading channel. The purpose of this simulation is to compare the technique over these two wireless channels and hence assess which channel provides better results for this technique. The graphs below show the results for probability of detection with varying Signal to Noise Ratio.

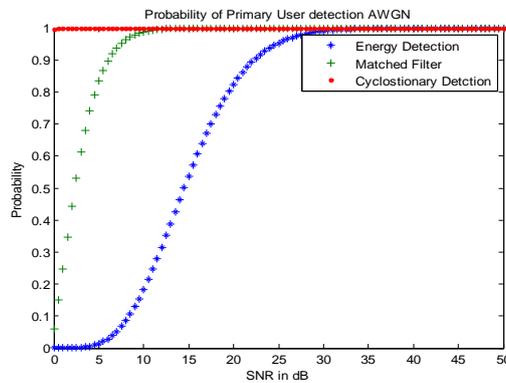


Figure 1. spectrum sensing technique under AWGN channel

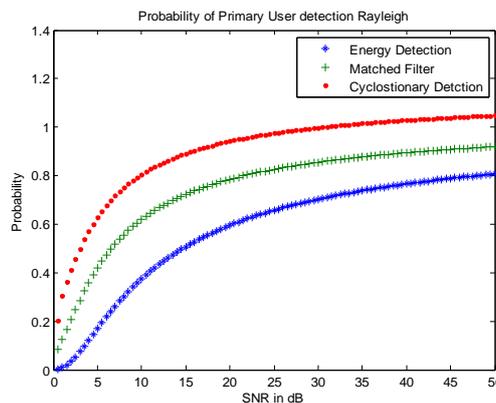


Figure 2. spectrum sensing technique under RAYLEIGH channel

VI. CONCLUSIONS

Spectrum is a very valuable resource in wireless communication systems and it has been a major research topic from last many decades. Cognitive radio is a promising technology which enables spectrum sensing for opportunistic spectrum usage by providing a means for the use of white spaces. Consider the challenges increase by cognitive radios, the use of spectrum sensing method appears as a vital need to achieve satisfactory results in terms of efficient use of available spectrum and limited interference with the licensed primary users.

We presented the performance of energy detection, matched filter and cyclostationary detection using AWGN and RAYLEIGH channel with probability detection to get better performance in spectrum sensing techniques. From above fig. we can conclude that the AWGN channel performance better then the wireless channels RAYLEIGH.

REFERENCES

- [1] S.Taruna, Bhumika Pahwa, Ikpreet Kaur “Assessment of Energy Detection Spectrum Sensing Under Different Wireless Channels” 2014 IEEE International Advance Computing Conference (IACC)
- [2] Sumit Lohan and Rita Mahajan “Performance Evaluation of New Energy Detection Based Spectrum Sensing Methods in Cognitive Radio” International Journal of Scientific & Engineering Research, Volume 4, Issue 7 July 2013
- [3] Omkar S. Vaidya and Vijaya M. Kulkarni “Analysis of Energy Detection Based Spectrum Sensing Over Wireless Fading Channels In Cognitive Radio Network” Volume 3, Issue 3, March 2013
- [4] Mr. Pradeep Kumar Verma, Mr. Sachin Taluja, Prof. Rajeshwar Lal Dua “Performance analysis of Energy detection, Matched filter detection & Cyclostationary feature detection Spectrum Sensing Techniques.”September 2012
- [5] Md. Shamim Hossain, Md. Ibrahim Abdullah, Mohammad Alamgir Hossain “Energy Detection Performance of Spectrum Sensing in Cognitive Radio” I.J. Information Technology and Computer Science, 2012, 11, 11-17 Published Online October2012 in MECS
- [6] Komal Arora, Ankush Kansal & Kulbir Singh “pComparison of Energy Detection Based Spectrum Sensing Methods over Fading Channels in Cognitive Radio” International Journal (SPIJ), Volume (5): Issue (2): 2011.