

A Review on Performance Analysis of Energy Detection Technique for Cognitive Radio Over Different Fading Channels

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ABSTRACT: The rapid growth in wireless communication systems has made the problem of under utilization of spectrum. To solve this problem the concept of cognitive radio (CR) emerged, the main goal of which is to provide adaptability to wireless transmission through dynamic spectrum access (DSA) so that the utilization of the frequency spectrum can be enhanced without losing the benefits associated with spectrum allocation. To sense existence of licensed user, Energy Detection based spectrum sensing technique is used over different wireless fading channels. In the energy detection approach, the radio-frequency (RF) energy in the channel or the received signal strength indicator is measured to determine whether the channel is idle or not. This paper gives the study of energy detection based spectrum sensing technique. Performance is done under three different fading channels i.e. Rayleigh, Nakagami and Rician. Probability of detection, Probability of missed detection and probability of false alarm are the design metrics used for analyzing the system over all different channels.

KEYWORDS: Cognitive Radio , Energy Detection, Fading Channels, Spectrum Sensing, Pd, Pfa, Pmd, nakagami,rayleigh, rician, Primary User (PU),Secondary User (SU).

I. INTRODUCTION

The available radio spectrum is limited and it is getting crowded day by day as there is increase in the number of wireless devices and applications. In the studies it has been found that the allocated radio spectrum is underutilized and the approach of radio spectrum management is not flexible, . In the present scenario, it has been found out that these allocated radio spectrums are free most of the time i.e. They are inefficiently used depending upon the geographical area. And this underutilization is due to the fact that a licensed user may not fully utilize the spectrum at all times in all locations.

The issue of spectrum underutilization in wireless communication can be solved in a better way using Cognitive Radio. Cognitive Radio (CR) is a promising technique to mitigate the scarcity of spectrum by sensing the spectrum, detecting the unused licensed bands, and efficiently utilizing these under-utilized bands. Energy detection is the most popular spectrum sensing method since it is simple to implement and does not require any prior information about the primary signal. The signal is detected by comparing the output of the energy detector with a threshold which depends on the noise floor. The performance of energy detector can be analyzed using ROC (Receiver operating characteristics) curves Energy detector performance can be expressed with two parameters: detection probability and false alarm probability [7 –11]. First parameter affects the radio system's interference level and the second the cognitive network spectral efficiency. The main objective is to study and analyze energy detection technique over various fading channels like additive white Gaussian noise (AWGN), Rayleigh, Rician and Nakagami.

II. RELATED WORK

The fundamental concept of Cognitive Radio has been discussed in detail in a paper by S.Haykin, [2]. It states that spectrum utilization can be improved significantly by making it possible for a secondary user to access a spectrum hole unoccupied by the primary user at the right location and the time in question. Cognitive radio has been proposed to promote the efficient use of the spectrum by exploiting the existence of spectrum holes. J. Mitola et al. [3] elaborated the need for cognitive radios by considering the example of an equalizer. Global System for Mobile Communications (GSM) radio's equalizer taps reflect the channel multipath structure. Software radio processing capacity is wasted

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running a computationally intensive equalizer algorithm when no equalizer is necessary. That processing capacity could be diverted to better use, or part of the processor might be put to sleep, saving battery life. In addition, the radio and network could agree to put data bits in the superfluous embedded training sequence, enhancing the payload data rate accordingly. Software radios were considered to be the platforms for personal communication systems but the contemporary process of modifying radio etiquettes was quite cumbersome as there was no way to represent the information about the radio environment and this limited the flexibility and responsiveness of the radio to the network and user.

In addition to it, recent rapid growth of wireless communications has made the problem of spectrum utilization ever more critical. On one hand, the increasing diversity and demand of high quality-of-service applications have resulted in overcrowding of the allocated spectrum bands, leading to significantly reduced levels of user satisfaction. The problem is particularly serious in communication-intensive situations such as after a ballgame or in a massive emergency (e.g., the 9/11 attacks). On the other hand, major licensed bands, such as those allocated for television broadcasting, amateur radio and paging, have been found to be grossly underutilized, resulting in spectrum wastage. J. Ma et al. [1] described that depending on the location, time of the day, and frequency bands, the spectrum actually is underutilized. However, those unused portions of the spectrum are licensed and thus cannot be used by systems other than the license owners. This has prompted the FCC to propose the opening of licensed bands to secondary users and given birth to cognitive radio. Cognitive radio allows for usage of licensed frequency bands by secondary users. However, these secondary users need to monitor the spectrum continuously to avoid possible interference with the licensed users. The IEEE has formed a working group (IEEE 802.22) to develop an air interface for opportunistic secondary access to the TV spectrum via the cognitive radio technology.

Budiarjo et al.[4] et al. proposed the use of TDCS as transmission technology for Cognitive Radio. Transform domain communication system (TDCS) is a single carrier transmission where its bandwidth can be divided into smaller sub-bands. In this way it is easier to locate the part of the band occupied by the licensed users and then not to put energy on that region. C. Han et al. [5] suggested a new implementation of TDCS, i.e. OFDM-based TDCS in which the complex RAKE receiver is avoided. However, one disadvantage of this OFDM-based TDCS is that the overhead may be relatively large, when the channel multipath delay is very large.

K. B. Letaief et al.[6] illustrated that Cognitive radio technology will enable the users to perform the functions like Spectrum Sensing, Spectrum Management, Spectrum Sharing and Spectrum Mobility. One of the most important components of CR is the ability to measure, sense, learn, and be aware of the parameters related to the radio channel characteristics, availability of spectrum and power, interference and noise temperature, radio's operating environment, user requirements, and applications. The most effective way to detect the availability of some portions of the spectrum is to detect the PUs that are receiving data within the range of a CR. However, it is difficult for the CR to have a direct measurement of a channel between a primary transmitter and receiver. Therefore, most existing spectrum sensing algorithms focus on the detection of the primary transmitted signal based on the local observations of the CR. S. Chaudhari et al. [14] proposed a simple and computationally efficient spectrum sensing scheme for OFDM based primary user signal using its autocorrelation coefficient and a decentralized sequential detection scheme is used to combine the soft decisions (autocorrelation-based LLRs) from the cooperating secondary users at the FC (Fusion Centre). The performance of Sequential detection is improved in comparison to the FSS (fixed sample size) detection. A robust spectrum sensing algorithm for OFDM modulated signals at low SNR is given by H.W. Chen et al. [15]. In this work, effects of multiple channels and CFO (Carrier Frequency Offset) have also been taken into account. By using this technique, a shorter sensing time by 1/3 is achieved as compared to the original system in the same performance of -20dB.

F.F. Digham et al. [7], illustrated that, in energy detector, the received signal is first filtered with a band pass filter in bandwidth to normalize the noise variance and to limit the noise power. The output signal is then squared and integrated. The conventional energy detection method assumes that the primary user signal is either absent or present and the performance degrades when the primary user is absent and then suddenly appears during the sensing time. T. S. Shehata et al [8] proposed a method to improve the performance of Energy detection based spectrum sensing method. In this proposal, a side detector is used which continuously monitor the spectrum so as to improve the probability of detection. The Primary user uses a QPSK signal, the sampling frequency is 8 times the signal BW. A 1024-point FFT is used to calculate the received signal energy. Simulation results

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showed that when primary users appear during the sensing time, the conventional energy detector has lower probability of detection as compared to the proposed detector.

N. Reisi et al. [9] analyzed the performance of energy detector based spectrum sensing method over fading channels. In his paper, he also presented the relation between the number of samples and Signal to noise ratio. Simulation results showed that for a 5dB decrease in the SNR, the required number of samples will be multiplied by ten.

P. D. Sutton et al. [10] suggested a spectrum sensing method which utilizes this feature of the transmitted signal. This method offers advantages of little signalling overhead and short signal observation times. A limitation of cyclostationary signatures generated using single OFDM subcarrier set mapping is the sensitivity exhibited to frequency-selective fading. The effects of frequency selective fading are overcome by increasing the frequency diversity of the cyclostationary signature. T. Ikuma et al. [11] analyzed and compared the performance of three different types of spectrum sensing algorithms: the energy detector, autocorrelation detector and the cyclic autocorrelation detector. Energy detector is the simplest algorithm and is the optimal detector if the noise power is perfectly known. The autocorrelation detector does not require exact knowledge of the noise power. In addition to it, the computational complexity of this algorithm is reasonably low. The cyclic autocorrelation detector has an added computational complexity over the autocorrelation detector.

S. M. Mishra et al.[12] and E. Visotsky et al. [22] used two rules. One used some kind of joint detection and other is based on making hard decisions to mitigate the sensitivity requirements on individual radios. J. Unnikrishnan et al. [13] proposed a fusion rule in which linear quadratic detector is used for cooperative detection. Linear quadratic detector is a detector that compares a linear-quadratic function of the local decisions with a threshold. Simulation results showed that the LQ detector is seen to give around 2-3 times the detection probability as that of the single sensor detector for the interference probability values considered even though the observations are highly correlated.

D. He et al. [18] suggested a method in which the spectral power of primary users (PUs) can be amplified, and the signal-to-noise ratio (SNR) of a received signal can be increased using SR. This ensures that the detection probability of the proposed approach is higher than that of the traditional energy detector and about 5dB SNR improvement is obtained. Z. Han et al. [21] suggested a network structure in which the spectrum sensing task is separated from the secondary users (secondary users). The sensing devices for the secondary users are placed within the networks of licensed users (primary users). These sensing devices sense the primary users' activity and also decide whether to permit a secondary user's transmission.

Z. Quan et al. [16] proposed a spectrum sensing method which work reliably at low SNR. The basic strategy is to correlate the periodogram of the received signal with the a priori known spectral features of the primary signal. Simulation results show that the proposed sensing technique can reliably detect analog and digital TV signals at SNR levels as low as -20 dB. J. F. Segura et al. [17] suggested a GLRT (Generalized Likelihood Ratio Test) based spectrum sensing method by exploiting the statistics of the received signal and the prior knowledge on the channel, noise and data signal. The proposed method is used when the secondary users have only a small number of signal samples. Results showed that the simple non-iterative GLRT sensing algorithm, offers the best performance in all systems under considerations.

K.W.Choi et al. [19] given a scheme which adaptively decides whether to sense the channel or to transmit the user data based on previous sensing results thereby improving the spectrum utilization. Two thresholds are used and channel utilization of 0.75 and a collision probability of 0.01 by choosing 0.015 as the value of lower threshold, is obtained. In cognitive radio (CR) networks, there is a trade-off between two conflicting goals at the same time: one is to maximize its own transmit throughput; and the other is to minimize the amount of interference it produces at each primary receiver. R. Zhang et al.[20] in his work, made use of multiple antennas to effectively balance between spatial multiplexing for the secondary transmission and interference avoidance at the primary receivers. Results showed that even under stringent interference-power constraints, substantial capacity gains are achievable for the secondary transmission by employing multi-antennas at the secondary transmitter. Two major challenges exist in the development and deployment of cognitive radio networks: spectrum sensing and hidden terminal problem.

III. SYSTEM DESIGN

Energy detector is the most popular way of spectrum sensing because of its low computational and implementation complexities. The receivers do not need any knowledge about the primary users. An energy detector (ED) simply treats the primary signal as noise and decides on the presence or absence of the primary signal based on the energy of the observed signal. The process flow of the energy detector is given in fig. 1, the received signal is passed through the filter followed by ADC then squared those values and average over the observation interval. Then the output of the detector is compared to a pre defined threshold value to decide whether the primary user is present or not. Output is considered as the test statistic to test the two hypotheses H_0 and H_1 .

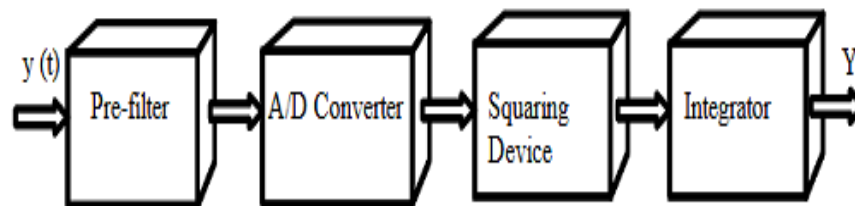


Fig1. Structure of Energy Detector

The received signal contains two binary hypothesis-testing dilemmas [12]:

H_0 : Primary user is absent.

H_1 : Primary user in operation.

The probability of correct detection P_d , probability of false alarm P_{fa} and probability of missed detection P_{md} are the key metric in spectrum sensing, given respectively as:

$$P_d = \text{Prob. \{Decision = H1/H1\}} \quad \dots(1)$$

$$P_{fa} = \text{Prob. \{Decision = H0/H0\}} \quad \dots (2)$$

$$P_{md} = \text{Prob. \{Decision = H0/H1\}} \quad \dots(3)$$

Energy detection represent the most popular spectrum sensing schemes, its objective is to determine whether H_0 or H_1 is true; this is achieved by sensing the energy of signal. There are two possibilities for the received signal. First one is noise alone and the other one is signal plus noise. This signal is modeled as a deterministic signal with unknown parameters. In the context of cognitive radio, this model is particularly important when considering the security issues to be handled. The receiver is to decide on the presence of this unknown deterministic signal based on the output of the integrator. The propagation of radio signals significantly affected by the physical channel in several ways. Some of the main channel effects can be described by path loss, slow fading, fast fading, Doppler, delay and angle spreads as follows.

- Fast Fading - Caused by multipath propagation. Rapid fluctuations are observed in the received signal amplitude.
- Path Loss - Caused by many factors including antenna, filter and propagation losses. Depends heavily on the propagation medium and the wireless environment.
- Slow Fading - Caused by shadowing etc due to mountains, buildings etc.
- Doppler Spread - Also known as time- selective fading.
- Delay Spread - Also known as frequency- selective fading.
- Angle Spread - Also known as or space- selective fading.

In this paper , we are interested to analyze the technique over fast fading channels such as Rayleigh, Rician and Nakagami.

A. Rayleigh Distribution:

In mobile radio channels, the Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal, or the envelope of an individual multipath component. It is well known that the envelope of the sum of two quadrature Gaussian noise signals obeys a Rayleigh distribution.

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The Rayleigh fading model considers urban multipath features, especially effects of the ionosphere and troposphere. It describes the statistical time varying nature of the received envelope of a flat fading signal or the envelope of an individual multipath component.

B. Rician Fading Distribution:

When there is a dominant stationary signal component present, such as a line-of-sight propagation path, the small-scale fading envelope distribution is Rician. In such a situation, random multipath components arriving at different angles are superimposed on a stationary dominant signal. At the output of an envelope detector, this has the effect of adding a dc component to the random multipath. Just as for the case of detection of, a sine wave in thermal noise, the effect of a dominant signal arriving with many weaker multipath signals gives rise to the Rician distribution. As the dominant signal becomes weaker, the composite signal resembles a noise signal which has an envelope that is Rayleigh. Thus, the Rician distribution degenerates to a Rayleigh distribution when the dominant component fades away.

C. Nakagami Fading Distribution:

In contrast to the Rayleigh distribution, which has a single parameter that can be used to match the fading-channel statistics, the Nakagami- is a two-parameter distribution, with the parameters m and K . As a consequence, this distribution provides more flexibility and accuracy in matching the observed signal statistics. The Nakagami-distribution can be used to model fading-channel conditions that are either more or less severe than the Rayleigh distribution, and it includes the Rayleigh distribution as a special case. m is the Nakagami- m fading parameter, describing the severity of fading; $m < 1$ suggests severe fading, while $m > 1$ indicates less severe fading.

IV. CONCLUSION

In this paper a review of the Energy detection technique for spectrum sensing in CR technology was presented. Energy Detection is introduced as a figure of merit. The performance metrics like probability of detection, probability of false alarm and probability of missed detection will be used to analyze the system over fading channels (Rayleigh, Ricean and Nakagami). Energy detection has been adopted as an alternative spectrum sensing method for CRs due to its simple circuit in the practical implementation and no information requires about the signal needed to detect.

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