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Spectrum Sensing using Energy Detection

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ABSTRACT

Spectrum sensing used to detect the presence of the primary users in a licensed spectrum, which is a fundamental problem for cognitive radio. Increasing efficiency of the spectrum usage is an urgent due to increasing demand for higher data rates, better quality of services and higher capacity. Cognitive radios (CRs) have been proposed as a possible solution to improve spectrum utilization by enabling opportunistic spectrum sharing. The main requirement for allowing CRs to use licensed spectrum on a secondary basis is not causing interference to primary users. Spectrum sensing allows cognitive users to autonomously identify unused portions of the radio spectrum, and thus avoidinterference to primary users. In this work, energy detection technique is considered for spectrum sensing, and the performance evaluation of an energy detector is presented.

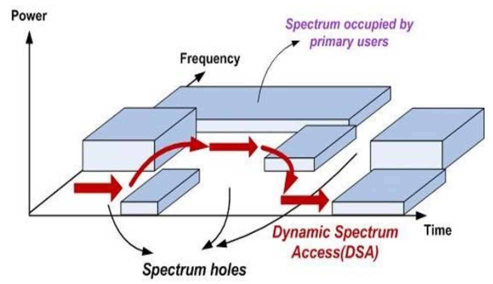
KEYWORDS:Cognitive Radio, Spectrum Sensing, Energy Detection, licensed spectrum, efficiency.

1. INTRODUCTION

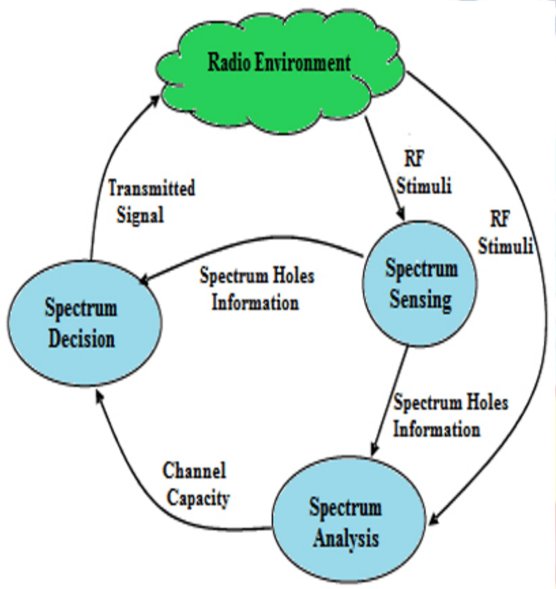
The need for high data rates is increasing as a result of the transition from voice-only communications to multimedia type applications. To facilitate high data rates, limited spectrum availability and static spectrum allocation methods are the barriers to overcome. Dynamic spectrum access (DSA) or opportunistic spectrum access (OSA) is proposed by the FCC as an alternative policy to solve thesespectrumshortage and inefficiency problems.Cognitive radio, originally proposed is a promising technology to avoid the underutilization of the wireless spectrum by dynamic access of available spectral opportunities. In cognitive radio terminology, primary user is defined as the licensed or authorized owners of a given frequency band, which has a higher priority of using the spectrum band. On the other hand, cognitive user is defined as the unlicensed or secondary user that is allowed to opportunistically use the spectrum band when the primary user is absent and has a lower priority on the usage of the spectrum. According to the FCC, the term cognitive radio can be defined as follows

"A radio or system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify system operation, such as maximize throughput, mitigate interference, facilitate interoperability."

Based on this definition, the two main characteristics of a cognitive radio that distinguish it from conventional radio devices are cognitive capability and reconfigurability.



The cognitive radio tasks as well as its interaction with the radio environment are illustrated in Figure



As can be seen from Figure, the cognitive cycle consists of three major components which are spectrum sensing, spectrum analysis and spectrum decision.

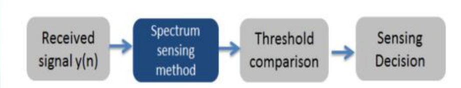
• Spectrum sensing: In spectrum sensing, a cognitive radio observes the frequency band and gathers necessary information regarding its surrounding radio environment. Based on the information captured, the cognitive radio is then able to detect any spectrum holes.

• Spectrum Analysis: Once spectrum holes are detected using spectrum sensing, each of the spectrum bands is characterized based on the local observation of the cognitive radio as well as the statistical information of the primary user network.

• Spectrum Decision: Based on the spectrum analysis, the cognitive radio determines the operating parameters such as the data rate, the transmission mode and the bandwidth available for the transmission. The most appropriatespectrum band is selected based on the spectrum band characterization and the user requirements

2. SPECTRUM SENSING FOR COGNITIVE RADIO

A cognitive radio is designed to measure, learn, sense, be aware of the changes in its surrounding and adapt itself to the radio's operating environment, which makes spectrum sensing an important component for the establishment of cognitive radio networks. Spectrum sensing enables a cognitive radio user to determine the spectrum availability in order to improve the spectrum's utilization without causing anyharmful interference to the primary user. This capability is required in two scenarios. The first scenario is when the cognitive users detect that a certain frequency band is not being used by the primary user. In this case, the primary user has stopped transmission and there exists a spectrum opportunity. The second scenario is when the cognitive users monitor the frequency band during its transmission to detect the existence of the primary user in order to vacate the channel without causing any significant interference to the primary user. Figure below shows the mechanism ofspectrum sensing in cognitive radios



The signal y(n) is passed through the spectrum sensing detector and the resultant detector signal T is compared with the threshold. If $T \geq$ threshold then PU signal is present. If $T <$ threshold then PU signal is absent. Here the threshold is estimated dynamically at each iteration. As long as primary user signal is absent, the secondary user can use the vacant spectrum.

3. METHODOLOGY

Energy detection is the most widely used sensing technique and it is the simplest form of sensing because of its simplicity and low computational and implementation complexities. It does not require any information on the primary user signals and hence, it is considered to be a blind detection technique. In energy detection, the presence or absence of the primary user is detected based on the energy in the signal received by the cognitive user. In particular, the detection statistic of the energy detector, which is defined as the average or total energy of a certain number of observedsamples, is compared with a predetermined threshold in order to determine whether the primary user exists or is absent. The performance of the energy detector is evaluated in terms of the probability of detection and the probability of false alarm. The probability of detection is defined as the probability that the energy detector correctly decides on the primary user's existence in the spectrum while the probability of false alarm denotes the probability that the energy detector decides that the primary user is present while it is actually absent. The goal of energy detection is to maximize the probability of detection subject to a constrained/predefined probability of false alarm.

4. PERFORMANCE ANALYSIS OF THE ENERGY DETECTION

The performance of the CR is evaluated in terms of the probability of detection.

Under binary hypothesis H0, signal model is

$$x(n) = w(n)$$

Under hypothesis H1, signal model is

$$x(n) = s(n)+w(n)$$

where x(n) is received signal, s(n) is primary user signal, typically binary phase shift keyed signal follows the Gaussian distribution. w (n) is the Gaussian noise signal with a zero mean.

$\boldsymbol{P_D}$ (Probability of detection): Probability of deciding H_1 when H_1 is true.

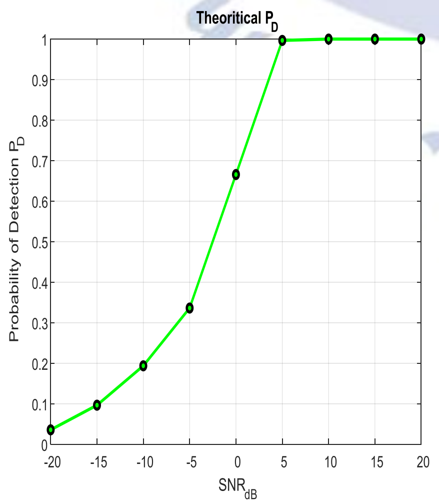
$$P_D = Q\left(\frac{\gamma - E}{\sigma\sqrt{E}}\right)$$

$\boldsymbol{P_{FA}}$ (Probability of False Alarm): Probability of deciding H_1 when H_0 is true.

$$P_{FA} = Q\left(\frac{\gamma}{\sigma\sqrt{E}}\right)$$

$$\gamma \;= Q^{-1}(P_{FA})\sigma\sqrt{E}$$

where 'E' is the primary user signal energy, 'γ' is the threshold and 'σ' is the variance of the signal.



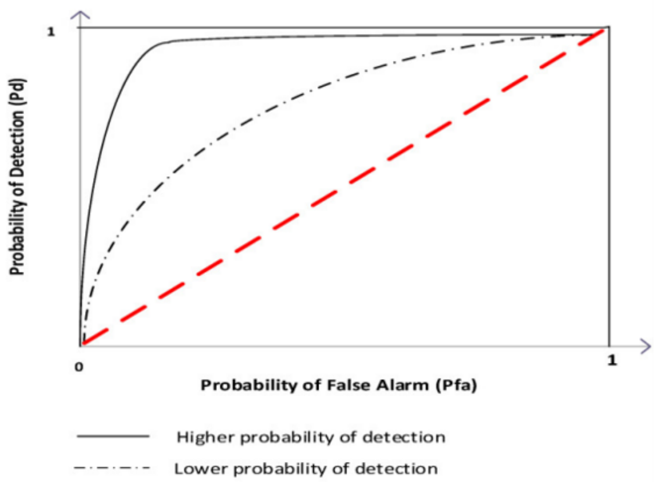
Theoretical probability of detection

As we increase the SNR the Probability of Detection increases and approaches to unity. Probability of Detection increases with increase in SNR.

5. RECEIVER OPERATING CHARACTERISTIC CURVES AND PRACTICAL OUTCOMES

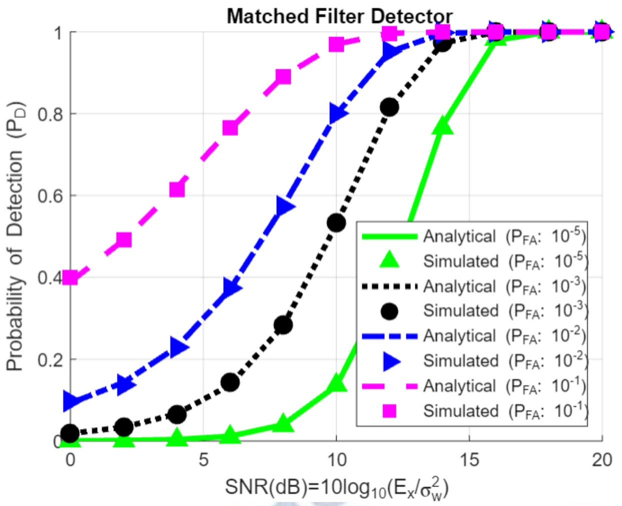
The interdependence between the probability of signal detection and the false alarm probability has been mostly expressed through receiver operating characteristic (ROC) curves. The different spaces above and below the diagonal (also known as the line of no-discrimination) identify the quality of ED. If the ED process can be expressed as the line of no discrimination, this means that the quality of the ED process corresponds to a random guess. Generally, the ROC space above the diagonal represents good detection results (better than random) while the space below the diagonal line represents poor ED (worse than random). Hence, the ED will be less accurate if the curve is closer to the 45-degree diagonal of the ROC space.

The area under the curve is also a measure of the detection accuracy. A larger area under the curve means that there is better ED accuracy and vice versa.

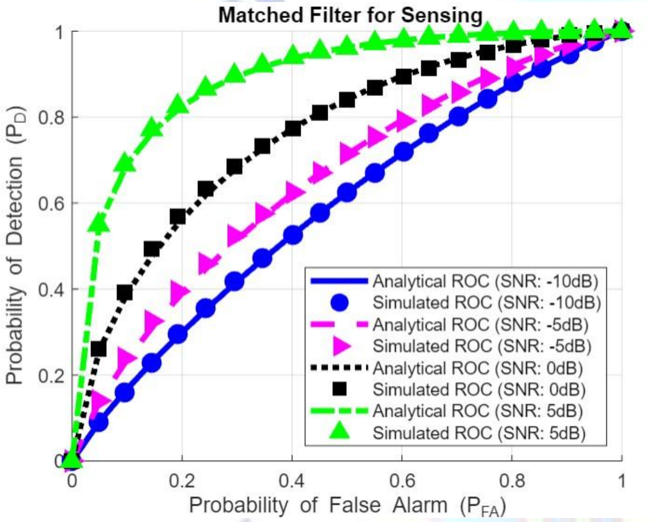


Practical Outcomes

The following diagram makes it easier to understand how we proceed.



SNR vs Probability of detection



Probabilityof False Alarm vs Probability of detection

6. FUTURE SCOPE AND CONCLUSION

The efficiency and sensitivity of detection rapidly decrease with rising in average fluctuation of noise power and gets worst in low SNR, but can be improved increasing the threshold factor. As we can see from the Fig 3 that the area of the curve which has the SNR of -10dB is small when compared to area of the curve with SNR 5dB. From this it can be concurred that the probability of detection with high SNR value is good in contrast with low SNR values.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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