Spectrum Sensing Techniques for OFDM-Based Cognitive Radio Networks

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Abstract

This project deals with a recent technology that has a significant impact on improving the spectrum utilization, which is the Cognitive Radio. Its main goal is to use the available spectrum efficiently to send huge amounts of data rates, without interfering with other users. In order to give the right decision whether the band is busy or not, Energy detection method was simulated and implemented over Gaussian and Fading

Scenario Definition

Primary user sends an OFDM signal to a third-party user, over ISM band. The secondary user (Cognitive Radio) harnesses the spectrum when it is unutilized.

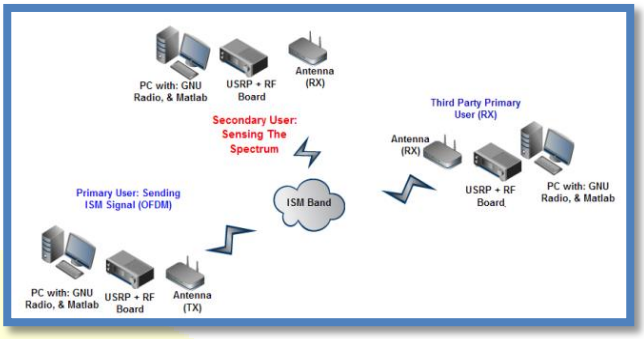

Figure 1: Scenario Definition

Theoretical Derivation

The Neyman-Pearson detector is used as a threshold detector on the likelihood ratio, yielding probability of detection $[P(d|\exists)]$, and probability of false alarm $[P(d|\nexists)]$. The optimal threshold derived is denoted by τ.

Hypothesis Testing

$$H_0: y(k) = Noise(k)$$

$$H_1: y(k) = Noise(k) + Signal_{primary}(k)$$

Deriving Receiver Operation Characteristics (ROC)

$$P_{false\ alarm}\ P(d|\nexists) = \Gamma_u(n\tau, n)$$

$$P_{detection} = P(d|\exists)_{Gaussian} = \Gamma_u\left(\frac{n\tau}{\sigma_w^2 + \sigma_s^2}, n\right)$$

$$P(d|\exists)_{fading} = e^{\frac{-\lambda}{2}} \sum_{n=0}^{u-2} \frac{1}{n!}\left(\frac{\lambda}{2}\right)^n + \left(\frac{1+\gamma'}{\gamma}\right)^{u-1}\left[e^{-\frac{\lambda}{2(1+\gamma')}} - e^{-\frac{\lambda}{2}} \sum_{n=0}^{u-2} \frac{1}{n!}\frac{\lambda\gamma'}{2(1+\gamma')}\right]$$

$$Threshold = \tau = \Gamma_u^{-1}(P_{FA}, N)$$

Simulation Phase

The primary user uses OFDM technology over fading and Gaussian channels.

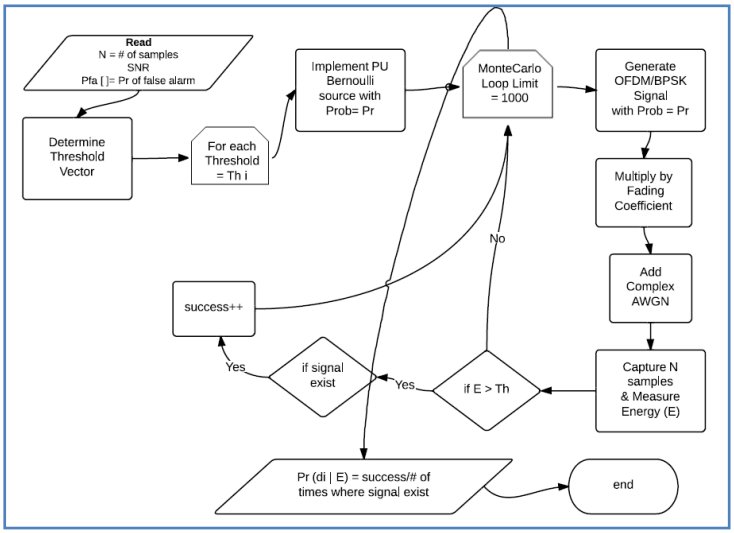

Figure 2: Monte Carlo Simulation

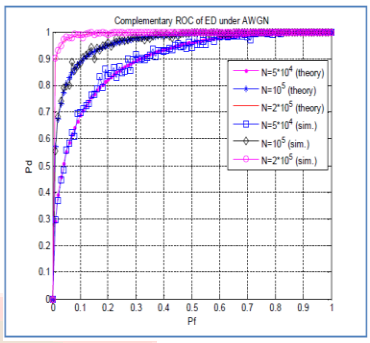

Figure 3: P_d P_f, Fixed Sensing Time

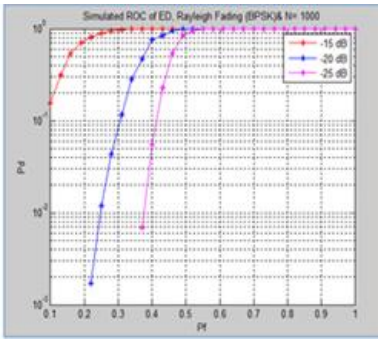

Figure 4: P_d vs. P_f, Fixed Sensing Time

Implementation Phase

A user friendly energy detector was implemented using GNU Radio. It basically utilizes the spectrum, when detecting a whitespace. The user is prompted to choose an appropriate threshold, frequency band, and sensing time. An audio feedback helps the user to recognize spectrum holes.

Figure 5: System Workspace

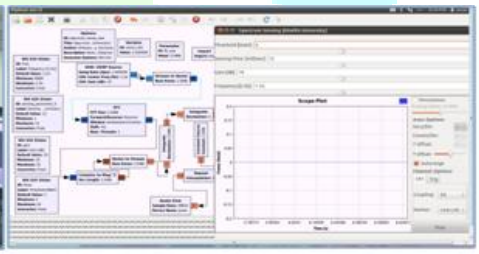

Figure 6: GRC Block (right) Diagram and Energy Detector (left)

The energy detector in Fig. 6 shows the detection process where '1' represents a signal being sent while '0' indicates that the spectrum bandwidth is empty for now and can be exploited, by the CR.