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ANALYSIS OF COGNITIVE RADIO ENERGY DETECTION TECHNIQUE BASED ON SPECTRUM SENSING

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ABSTRACT:
Cognitive radio is a modern technique for the effective utilization of electromagnetic spectrum. In Cognative Radio, there are many functions out of which spectrum sensing is one of the important function. Spectrum sensing is the method of detecting unused spectrum so as not to cause interference to the legal assigned users.

KEY WORDS: Wireless Communication, Cognitive Radio, Energy Detection, Dynamic Spectrum Access

INTRODUCTION:
Radio Spectrum is very important and is the only natural resource for usage by number of wireless services. This spectrum can be reused depending on some of the technical conditions. Practically, the number of users that can be served by radio spectrum is limited. The main aims of cognitive radios are to effectively utilize the radio band which is used scarcely without introducing interference to legal PU.

DEFINITION:
A CR basically senses the spectrum, understands its operating environment, identify the available temporary spectrum, adapt spectrum for transmission and learn its behaviour. Cognitive radio is a novel technology which improves the spectrum utilization by allowing secondary users to borrow unused radio spectrum from primary licensed users or to share the spectrum with the primary users.

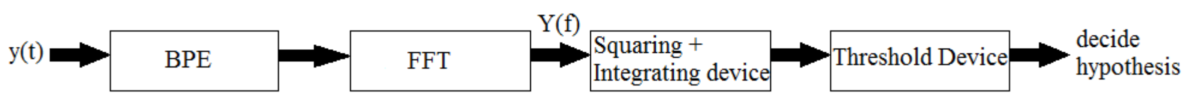
CYCLE OF CR:
Various steps involved in cycle of CR are: (i) Spectrum sensing, (ii) Spectrum sharing, (iii) Spectrum decision (iv) Spectrum mobility.

1. **SPECTRUM SENSING**:
It is one of the band awareness processes in which CR checks its frequency range platform space and physical area, identify the numeric of usage of PU and SU and also identify the available spaces in frequency. This function is performed either by single CR or by number of CRs thereby enhancing the complete accuracy.
2. **SPECTRUM DECISION:**
It depends on information of sensing the spectrum, CR choses time to begin its work, its particular technical factors, operating frequency. The basic aim of cognitive radio is to exchange as much information as can be and to assuage needed QoS, by not causing harmful interference to PUs. Also, CR can extract information from policy repository and regulatory repository so that to enhance its performance along with statistics of outage.
3. **SPECTRUM SHARING:**
As there are many of illegal users which are taking part in the regime of White Spaces, CR is designed to maintain balance within self-esteem of exchanging the data in effective way and to contribute the feasible
4. assets with CR and non CR users

TERMINOLOGIES IN CR:
CR capabilities
Full CR: Each function is considered which is observed
Spectrum Sensing CR: Considers only the Radio band out of complete EM spectrum

SPECTRUM RANGE LICENSES:
Licensed CR: Primary and Secondary Unlicensed CR The most popular techniques used in detecting primary transmitter are energy detection, matched-filter detection; Eigen-value based detection, cyclostationary detection and many more.

ENERGY DETECTION:
is the most common technique used in detection of primary transmitter due to its less implementation and computational complexities. In this technique the detector performs non-coherent detection and therefore don't require any prior knowledge of the primary transmitter. The signal Y (f) is obtained by passing the received signal y (t) through band pass filter and Fast Fourier Transform. The energy gained of signal is then calculated by integration and summing the information Y (f) over detection interval of time. The primary user is then encountered by correlating energy of received signal with the range of threshold. The threshold decision confides upon the level needed for Fake alarm and is much inclined to the uncertainty in Noise signal. This technique cannot differentiate between noise and primary signal and therefore has very low attainment under less SNR. Also this technique is unsuitable for the detection of Spread Spectrum signals as very complex signal processing algorithms are used for its detection.



Block diagram of Energy detection

EIGEN VALUE DETECTION:
Depends upon the Random Matrix theory. This technique is also non-coherent as no prior knowledge is required of the primary user. The advantage of this technique is that it is not implementation and computationally complex. The maximum Eigen value of signal is obtained to compare it with predefined threshold for the detection of primary user signal. The maximum Eigen value is calculated by passing the received through autocorrelation and covariance matrix

SPECTRUM SENSING PROBLEM FORMULATION:
With the help of two hypotheses of binary hypothesis problem of testing

$$H_0 \text{ denotes} : y(n) = w(n) \rightarrow (\text{PU unavailable})$$
$$H_1 \text{ denotes} : y(n) = x(n) + w(n) \rightarrow (\text{PU available})$$

Here, $y(n)$ is the signal received by primary user, n= 1, 2, 3…N where N is complete primary legal user's observing period length. $x(n)$ denotes the sample of primary legal user signal. $w(n)$ denotes the sample of AWGN (Additive White Gaussian Noise) having variance σ_n^2. Hypotheses H_0 say about the absence of primary user and Hypotheses H_1 say about the presence of primary user. The samples of noise are related to variance in way as mentioned:

$$w(n) \in N(0, \sigma_n^2)$$

FIXED THRESHOLD CLASSICAL ENERGY DETECTOR:

In energy detection technique considering fixed threshold, it analyzes the availability of primary user in the spectrum range. If the energy which is received of primary user comes out to be greater than the fixed threshold which was predetermined, the spectrum frequency band is considered to be busy and declares Hypotheses H_1. And if the energy received comes out to be less than the predetermined fixed threshold value, the spectrum can be declared as idle and hypotheses H_0 is considered in this case.

The statistic to be tested is given as:

$$D(y) = \sum_{n=0}^{N} y(n)^2$$

Here, y(n) denotes the received energy of primary signal, D(y) is the decision variable. The statistic to be tested follows central distribution chi-square beneath hypotheses H_0 and non-central distribution beneath hypotheses H_1.

$$D(y) = \begin{cases} N(N\sigma_n^2, 2N\sigma_n^4) & H_0 \\ N(N(P+\sigma_n^2), 2N(P+\sigma_n^2)^2) & H_1 \end{cases}$$

DYNAMIC THRESHOLD ENERGY DETECTION TECHNIQUE:

In this detection technique, we need to calculate two values of threshold so as to maximize the probability of detection and minimize the probability of false alarm. The average energy received of the primary legal user is defined as below:

$$D_{av} = \frac{1}{L}\sum_{k=1}^{L} D(y)_k$$

$D(y)_k$ is the energy received. We can also calculate noise uncertainty factor by dividing the maximum of noise variance by the average of all the noise variances.

The noise uncertainty factor is given as below:

$$\rho = \frac{\max_{1\le i\le L}({\sigma^2}_{n_i})}{\frac{1}{L}\sum_{i=1}^{L} {\sigma^2}_{n_i}}$$

We take into consideration two different cases for evaluating the new thresholds taking into account the effect of noise uncertainty:

Case 1. If $D_{av} \geq \gamma$, we estimate about the presence of primary user, and new threshold is calculated considering the effect of noise uncertainty i.e.

$$\gamma_{new} = \gamma/\rho$$

Case 2. If $D_{av} < \gamma$, we estimate about the absence of primary user, and the new threshold will be evaluated including effect of noise uncertainty as,

$$\boldsymbol{\gamma_{new} = \gamma\rho}$$

THEORETICAL ANALYSIS OF THE NEW PROPOSED SCHEME:

Depending upon what the algorithm estimate about primary user and what the actual status is about, we divide the theoretical study of our technique into four cases:

CASE1. TRUE PREDICTION:

PU is actually present, algorithm also declared hypotheses H_1. $\gamma_{new} = \gamma/\rho$ will be the new threshold that will increase the value of probability of detection.

CASE2. FALSE PREDICTION:

PU is actually absent, algorithm declared hypothesesH_1. $\gamma_{new} = \gamma/\rho$ will be the new threshold which will increase the value of probability of false alarm.

CASE3. TRUE PREDICTION:

PU is actually absent, algorithm also declared hypotheses $H_{0.}$ $\gamma_{new} = \gamma\rho$ will be the new threshold which will decrease the probability of false alarm.

CASE4. FALSE PREDICTION:

PU is actually present, algorithm declared hypotheses $H_{0.}$ $\gamma_{new} = \gamma\rho$ will be the new threshold and it will decrease the value of probability of detection.

GENERALIZED ENERGY DETECTOR:

In generalized energy detector, we take the power as a positive integer p instead of taking it as 2 as was in Classical Energy Detector.

In CED, the test statistic is given as

$$D(y) = \sum_{n=0}^{N} y(n)^2$$

While in GED, we take the test statistic as

$$D(y) = \sum_{n=0}^{N} y(n)^p$$

Here, p is a positive integer ranging from 1, 2…n.

With p=2, the GED becomes the CED which is a special case

3.1 RESULTS

Scenario 1:

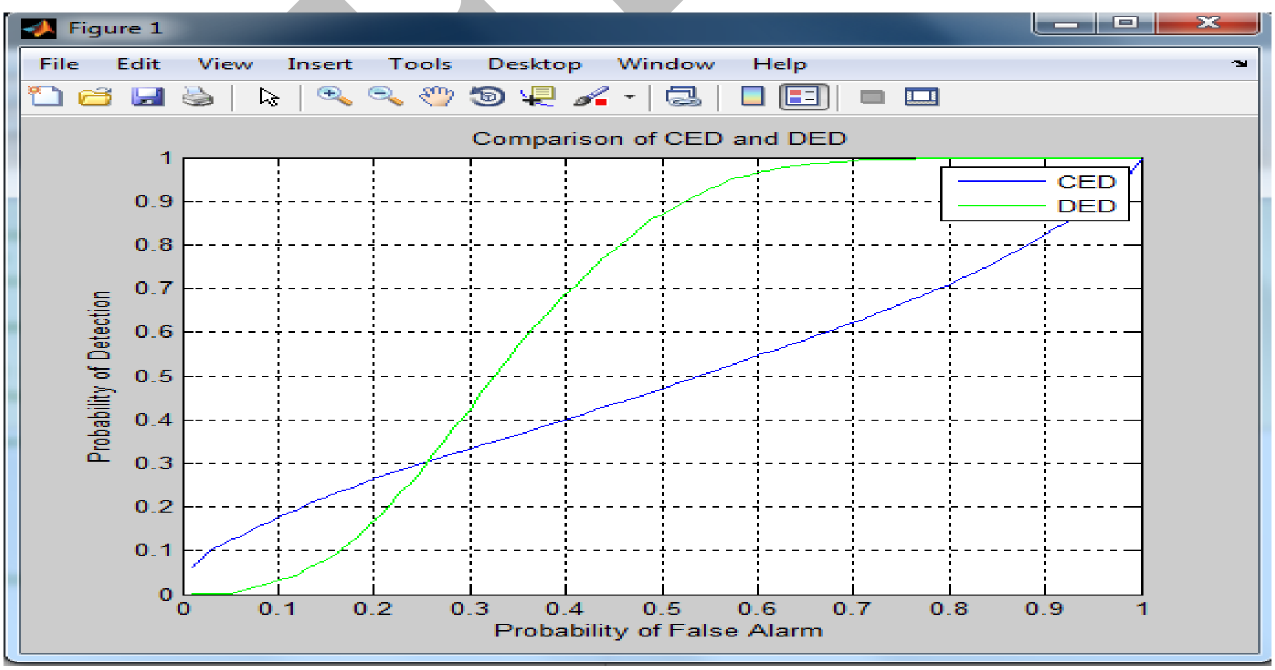


Figure Comparison of CED and DED

In the above graph, we are comparing Classical Energy Detector (CED) and Dynamic Energy Detector (DED). As shown, in DED we can see increase in probability of detection with min probability of false alarm.

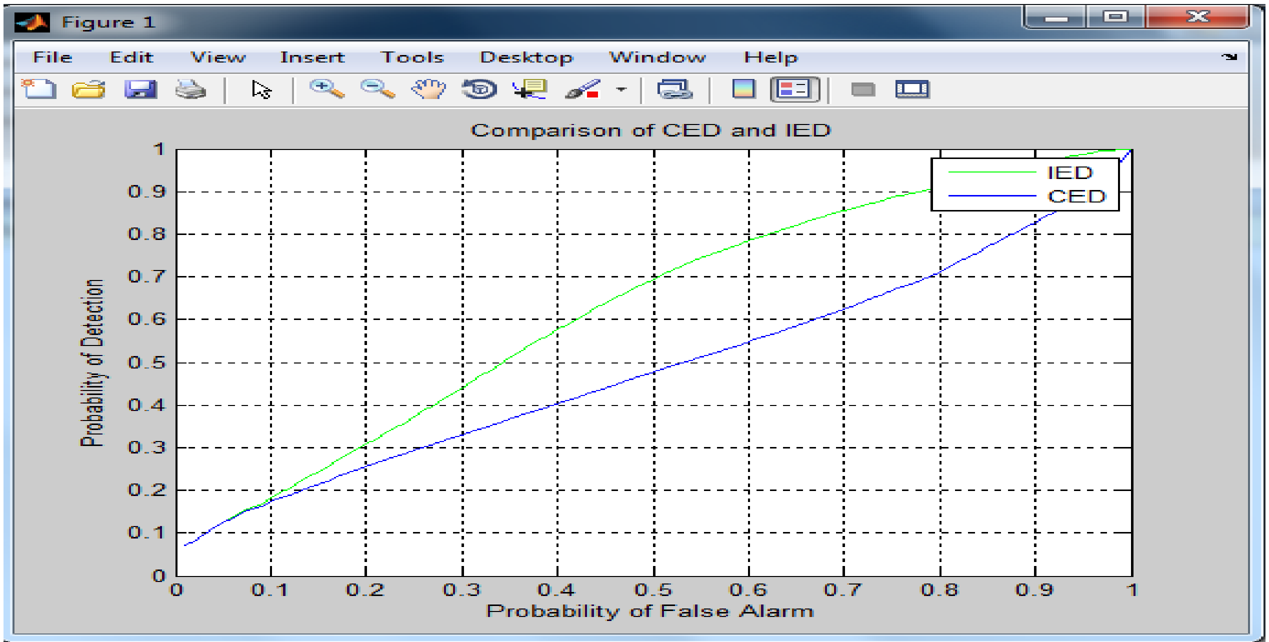
SPECIFICATIONS:

L=50

N=1000

SNR=-20db

For Improved Energy Detector

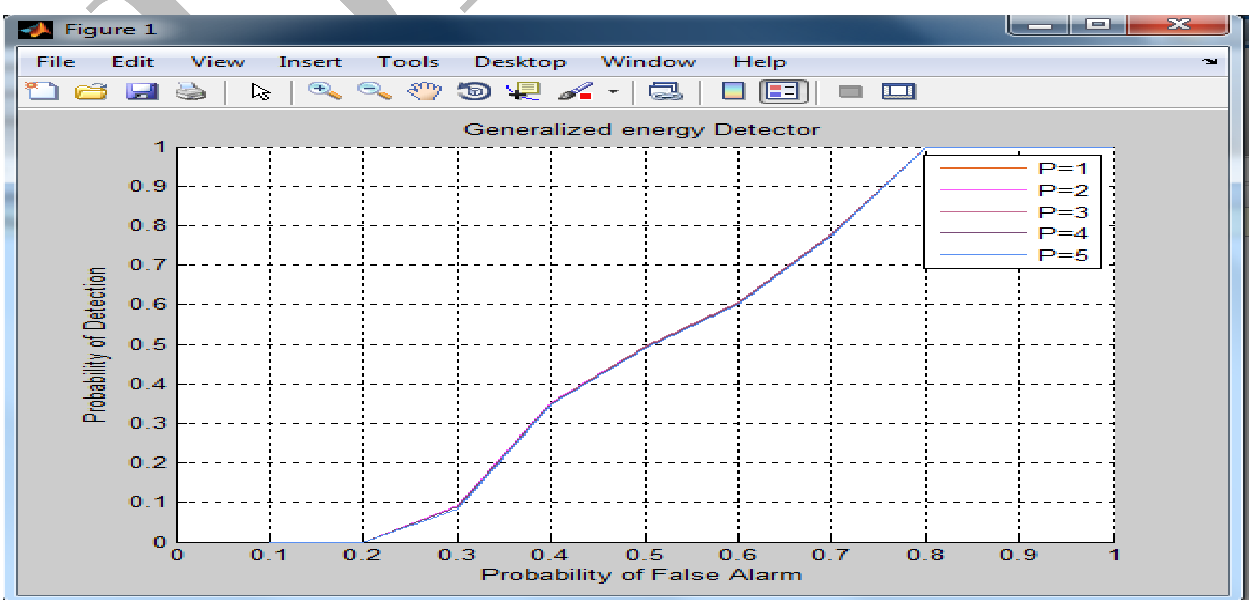


In the above graph, we are comparing Classical Energy Detector (CED) and Improved Energy Detector (IED). As shown, in IED we can see increase in probability of detection with min probability of false alarm.

SPECIFICATIONS:

- L=50
- N=1000
- SNR=-20db

For Generalized Energy Detector



CONCLUSION:

The dynamic threshold energy detection, improved energy detection and generalized energy detector is proposed in this paper for the spectrum sensing of Cognitive Radio. The proposed dynamic energy scheme depends on the current state of the primary user. Depending on this, dynamic thresholds are evaluated considering the effect of Noise Uncertainty. The thresholds evaluated are used to increase the value of P_d and decrease the value of P_{fa}. The performance of dynamic energy detection technique is optimized against the values of parameters. The proposed dynamic energy detection scheme proved to be 3.5 times better than the classical energy detection

Scheme. In improved energy detector, we calculate the average of all the energies received for N samples consecutive L periods of observations. If the average energy is greater than the predetermined threshold, we calculate the energy of the previous sample and compare now it with threshold. This technique is used to reduce the probability of False Alarm. In generalized energy detector, we take the power as a positive integer p instead of taking it as 2 as was in Classical Energy Detector. For different values of p, value of detection probability and false alarm probability is observed.

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