COOPERATIVE SPECTRUM SENSING BASED ON ADAPTIVE THRESHOLD FOR COGNITIVE RADIO

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Abstract - *Cognitive radio is a form of wireless communication, overcomes spectrum scarcity problem. In cognitive radio spectrum sensing plays a major role. There are various methods for spectrum sensing. Among all the spectrum sensing schemes energy detection is commonly used because of its low complexity. But in some cases where the signal to noise ratio is low , this scheme may not give better performance. So in order to enhance the performance of energy detection scheme we go for adaptive threshold. Adaptive threshold is a function of fixed threshold and SNR of primary user signal received at CR. However the individual CR may not give valid results due to Multipath fading and Shadowing. Therefore we go for cooperative spectrum sensing. In cooperative spectrum sensing(CSS) , each individual CR will sense the spectrum using adaptive threshold and give its decision to Fusion Center(FC). At fusion center all the binary decisions are fused together and give final decision about the availability of the spectrum. Compared to non-cooperative spectrum sensing cooperative spectrum sensing gives better performance.*

Keywords: *cognitive radio, spectrum sensing, energy detection, adaptive threshold, cooperative spectrum (CSS)*

1. INTRODUCTION:

In present technology wireless communication plays a major role and there is a huge demand for wireless spectrum. The Federal communication commission (FCC) will give permission to use the spectrum, known as Primary Users (PU) who are the licensed users. The unlicensed users are known as Secondary Users (SU). The fixed spectrum allocation policy results in the spectrum scarcity problem. Cognitive radio is a software defined radio form of wireless communication in which transceiver can detect which are in use and which are not and instantly move into the vacant channels without interfering the primary users. This optimizes the use of available radio-frequency (RF) spectrum while minimizing the interference to other users. The CR seeks for unused spectrum, also known as spectrum holes and use the empty spectrum in a opportunistic manner. To know whether primary user is present or not spectrum sensing is required by the secondary user. The CR sense its operational environment and able to adjust its operational parameters automatically and dynamically.

In cooperative spectrum sensing, each individual CR will give binary decision to the fusion center and the fusion center will give final decision about the availability of the spectrum. The output of fusion center is either one or zero indicates the presence or absence of primary user respectively. There are two different fusion schemes for spectrum sensing. If the data collected by every CR is shared to fusion center, it is called soft combining. If the decisions collected by individual CR is shared to fusion center then it is called hard combining. In case of decision fusion we use n-out-of-K rule, where K represents total number of CR's and 'n' represents the minimum number of CR's needed to detect the presence of primary user so that FC can declare the scanned spectrum as occupied. The value of n is optimized to reduce the total error rate. For minimising the probability of false alarm(Pf), detection threshold is optimized by keeping the probability of missed detection(Pmd) constant. There are various methods for spectrum sensing like energy detection, Matched filter detection and Cyclostationary feature detection. Among all the spectrum sensing schemes energy detection is mostly used because of its low computational complexity and it does not require any prior information of the primary user. Where as in other sensing schemes, it requires prior information of the primary user.

2. ENERGY DETECTION:

It is the simplest sensing technique which does not require any prior information of the primary user. This measures the received signal energy within the predefined bandwidth and time period. The measured energy is then compared with a threshold to determine the status(Presence/Absence) of the primary user. If the signal energy is greater than threshold value then it indicates the presence of primary user else it indicates absence of primary user.

The test statistics for energy detection is given as

$$T_i(X) = \left(\frac{1}{M}\right)\sum_{m=1}^{M}\left|x_i(m)\right|^2 \quad \text{............(1)}$$

$$x_i(m) = \begin{cases} u_i(m); H_0 \\ s_i(m) + u_i(m); H_1 \end{cases} \quad \text{............(2)}$$

where

$x_i(m)$= received signal at the ith second user

$s_i(m)$= received PU signal.

$u_i(m)$ =White gaussian noise with zero mean and variance

H_0 = Absence of primary user

M= Total samples collected by CR

H_1 = Presence of primary user

Energy detection is an essential and common approach to spectrum sensing since it has moderate complexities and can be implemented both in time domain and frequency domain. Energy detection scheme may not give valid sensing results in low SNR regions therefore we go for adaptive threshold. To adjust the threshold of detection, energy detector requires prior information of the primary user signal. Energy detection is not optimal but it is simple to implement, so it is widely adapted. The signal is detected by comparing the output of energy detector with threshold which depends on the noise floor. According to the sampling theorem, in order to represent the energy of finite number of terms over a duration T, we need approximately 2U samples where U=TW, defined as time bandwidth product.

$$P = 2\sigma_n^2 \quad \text{............ (3)}$$

3. COOPERATIVE SPECTRUM SENSING:

The individual CR may not give valid sensing results due to multipath fading and shadowing, therefore we go for cooperative spectrum sensing(CSS). In CSS, each CR will individually sense the spectrum using adaptive threshold and then transfer its decision to a central node also known as fusion center (FC). All the binary decisions (Di) received at FC are fused together and then final decision about the availability of spectrum is taken by FC. 'Di' is either 0 or 1 corresponding to absence or presence of primary user detected by CR.

All the one bit decisions collected by the fusion center are fused together with the logic rule:

$$Y = \sum_{i=1}^{k} D_i \quad \text{............(4)}$$

if $D_i >= n$; H_1

If $D_i <= n$; H_0

Here n is an integer which represents general voting rule i.e. n-out-of-K rule where K is the total number of CR's present and 'n' is the minimum number of needed to detect the presence of primary users. In Non-cooperative spectrum sensing only one CR is involved where as in cooperative spectrum sensing multiple CR's are used. Compared to non- cooperative , cooperative spectrum sensing gives better performance.

4. PROPOSED ADAPTIVE THRESHOLD:

In conventional (fixed) energy detection scheme a fixed threshold is calculated either by keeping probability of detection rate or probability of false alarm constant. In adaptive threshold method we vary the Threshold value depending upon the SNR of the primary user signal.

$$P_i' = \frac{\frac{2}{N}\ln(P_i) + \ln\left(\frac{\sigma_s^2 + \sigma_n^2}{\sigma_n^2}\right)}{\left[\frac{1}{\sigma_n^2} - \frac{1}{\sigma_s^2 + \sigma_n^2}\right]} \quad \text{...(5)}$$

P_i'=Adaptive threshold

$$SNR_P = \frac{\sigma_s^2}{\sigma_n^2}$$

$$P_i' = \frac{\frac{2}{N}\ln(P_i) + \ln(1 + SNR_P)}{\frac{SNR_P}{\sigma_n^2(1 + SNR_P)}} \quad \text{.......(6)}$$

P_i' is the proposed adaptive threshold which is being used in energy detection for local sensing at each CR. Therefore each cooperating CR makes a local binary decision by using adaptive threshold and forwards its one bit decision to the central entity(fusion center). The degradation of detection performance caused by noise average power fluctuation can be completely eliminated with a choice dynamic threshold factor which depends upon estimated noise variance. The error rate with cooperation is much lower than without cooperation based on threshold.

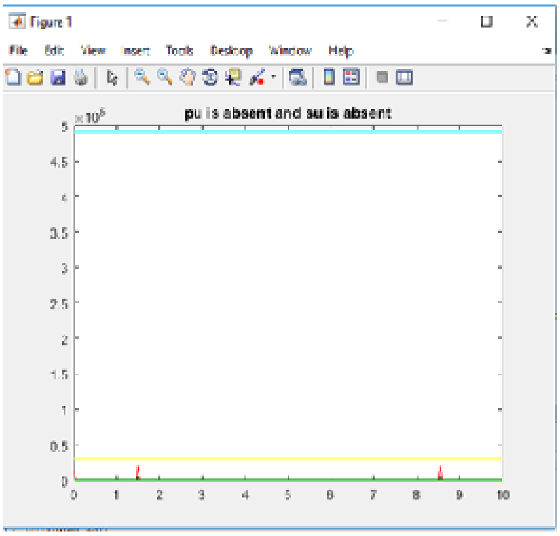

Figure 1.1: PU is absent and SU is absent

In the above figure, the energy of both primary user and secondary user lies below the threshold level. Therefore there is a empty band. The energy value lies below the two thresholds therefore there is a empty frequency band.

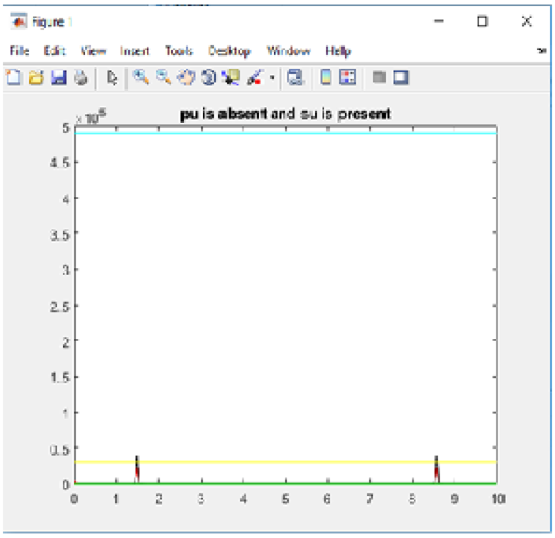

Figure1.2. PU is absent and SU is present

In this case, the energy of primary user signal lies below the two thresholds. Therefore there is a empty frequency band and therefore secondary user can occupy the empty frequency band. Black color represents secondary user signal, the energy value of the signal lies above the two thresholds therefore secondary user is present and primary user is absent

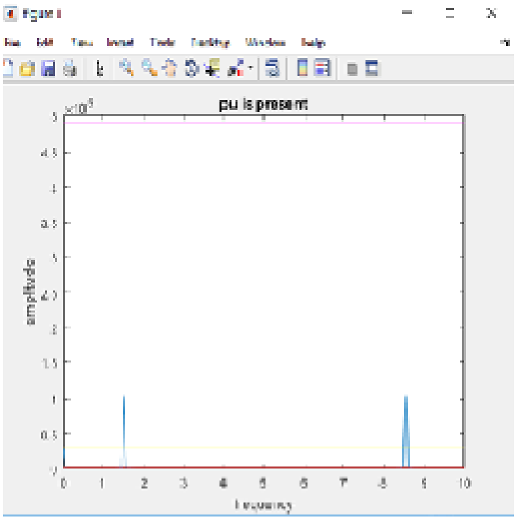

Figure1.3. PU is present

One simple threshold estimation option normally used for energy detector is to fix the threshold value above the noise level. Adaptive threshold able to adapt to the changing noise level. If we assume a certain threshold level, when the SNR ratio is low i.e. where the noise is high. If the noise exceeds the detection threshold, it may leads to false alarm. The energy detector may consider the noise as a signal since the noise exceeds detection threshold. Therefore we adjust the threshold value according to the SNR i.e when the SNR is low, we increase the threshold level to prevent the ED from considering noise as a signal.

CONCLUSION:

The simulation results shows better sensing performance of energy detection scheme based on adaptive threshold. Adaptive threshold with cooperation gives better probability of detection of the licensed user when more than one CR are involved in spectrum sensing are involved. The error rate w ith cooperation is much lower when compared to non-cooperate spectrum sensing.

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