Hybrid Spectrum Sensing Algorithm for Cognitive Radio Network

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ABSTRACT
Spectrum sensing plays a very provocative role in cognitive radio network. In order to utilize spectrum more efficiently and to exploit the primary user, spectrum sensing is accomplished. We proposed a new hybrid algorithm for detection of primary user in cognitive radio network. The theoretical analysis and simulation is also presented in this paper. This research work includes an analogy with Energy Based Detection and Cyclostationary Feature Detection. Our proposed algorithm is a flexible algorithm, the Cyclostationary feature algorithm act as feature extractor when primary user is present and function as detector when primary user is absent. The results show that it is optimum spectrum sensing algorithm under different SNR values. It has removed the shortcomings faced by both sensing algorithms i.e. Energy Based Detection and Cyclostationary Feature Detection.

Keywords
Power spectral density, cyclic correlation function, mean square spectrum, hybrid spectrum sensing.

1. INTRODUCTION
The swift increase in the high data rate applications lead the spectrum congestion issues in wireless communication. However novel studies show that spectrum underutilization is due to fixed assignment of spectrum policy. To overcome these problems cognitive radio [1-4] has been introduced as an emerging technique. As these applications are not needed all the time so the useful spectrum is wasted most of the time, as a result vacant spaces in spectrum are found which are called spectrum holes [5-7]. To utilize these spectrum holes the unlicensed user are allowed to transmit over this band. For this purpose Joseph Mitola for the first time presented the idea of smart radio in 1990s, according to him the radio must be made so smart that it has the quality to sense the radio surroundings and adapt itself according to situation [8][9]. The text "Cognitive Radio" was introduced by Mitola and Maguire in 1999.

The principal duty of every cognitive radio user in a cognitive radio network is to trace the primary users or licensed users whether they are present or not. By sensing the RF environment this is usually found out whether primary user is present or not and this process is referred as spectrum sensing [10-14].

In [15-16] the meaning of "Cognitive" is which is linked to remembering, thinking and reasoning. So we can say that a cognitive radio is a sharp radio which detects the radio surroundings, discovers from the history and produces intelligent decision to regulate its transmission parameters according to the status.

The interference with primary user should also be avoided because cognitive radio concept is used to utilize the spectrum in an efficient way. In order to avoid these interferences with primary user there are some algorithms used which firstly check the primary user and then adjust its transmission parameters.

The potentiality of a cognitive radio is to observe the radio operating surroundings with the goal of exploiting possibilities in spectrum band and to change the radio parameters. The principle of spectrum sensing is twofold: cognitive radio should identify the spectrum holes and second is cognitive radio should not interfere with primary user. Thus sensing needs some information of primary user which is transmitting power, modulation type, operating frequency etc. Spectrum sensing is assumed to be a detection problem [17].

The detection performance of primary users is assured by probability of detection and probability of false alarm [19-20]. Probability of detection indicates the probability of a cognitive radio user when the spectrum is really occupied by primary user. Whereas the probability of false alarm depicts the situation when the spectrum is free in reality but it is declared that primary user is present. Thus it can be concluded that probability of false alarm should be as small as possible and the probability of detection should be as large as possible. Since a miss content in the detection may direct to trouble with the primary user which could cut down the spectral efficiency.

The remaining the paper is managed as: theoretical background study is stated in section 2. Section 3, elaborates the proposed hybrid algorithm and its implementation. In section 4, the results are demonstrated. Ultimately section 5 comprises of conclusion.

2. THEORETICAL BACKGROUND
This algorithm is formed as the cascaded result of the Energy Based Detection and Cyclostationary Feature Detection therefore the background of both should be studied.

2.1 Energy Based Sensing
Energy detector is non-coherent algorithm also referred as radiometry or periodogram, which identify the primary user on the basis of its energy [7] [8].

Suppose that the detected signal is represented by the following mathematical form

$$y(t) = r(t) + n(t) \quad \text{.....1}$$

From the equation above represents the received signal noted by secondary user, points the transmitted signal of primary user and refers the Additive White Gaussian Noise. Therefore there are two hypotheses regarding to primary user either primary user is present ≠0 or absent = 0. So equation 1 can be modified into two further hypotheses as:

$y(t) = n(t)$ H_0…….....2

$y(t) = h(t) + n(t)$ H_1…….3

For non fading scenario second hypothesis is used which shows the amplitude gain of the channel. From the above theories we can also write the formula for energy of the signal:

$E = \sum |y(t)|^2$ …….....4

Once the energy of signal is calculated by the formula in eq. 4 then the calculated value is equated with a threshold value to judge the status of primary user (present/ absent).

This is the more elementary algorithm as its reckoning and implementation is easy also it does not demand any prior background knowledge about the primary user's signal [21-22].

Despite of these features there are certain drawbacks of this algorithm which are:

i- the probability to detect primary user takes more sensing time
ii- it cannot differentiate between a primary user, noise and interference
iii- to choose the exact value of the threshold
iv- not applicable when signal is direct sequence or frequency hoping
v- good only for narrowband signals
vi- not good results for low SNR value

2.2 Cyclostationary Feature Detection

Cyclostationary is a coherent algorithm used for detecting the primary user, by this method the presence of primary user is found by mining the periodicity present in the received signal. Periodicity exists in sine wave carriers, train of pulses, hoping sequences, spreading codes [23]. To check the primary user's presence instead of power spectral density cyclic correlation function is used in this method. Since it is understood that noise is wide sense stationary WSS having zero correlation whereas due to redundancy in signal due to periodicity, the modulated signal is Cyclostationary with spectral correlation [24]. This quality makes the Cyclostationary feature detection able to discriminate between primary signal and noise. That is why it can be stated that Cyclostationary feature detection is far more effective than energy based sensing method. Also this algorithm gives satisfactory results for low SNR values.

Below equation shows the cyclic spectral density of the primary signal as in [11, 25]

$S(f, \alpha) = \sum_{r=-\infty}^{\infty} \mathcal{R}y^{\alpha}(\tau) e^{-j2\pi\tau}$ ……..5

Where

$\mathcal{R}^{\alpha}(\tau) = E[y(n+\tau)y^*(n-\tau)e^{-j2\pi\alpha n}]$ ……..6

Is the cyclic autocorrelation function, y is received signal and α is the cyclic frequency. This cyclic frequency can be supposed and is used to obtain the features of the primary user's signal. In fact it itself is also a feature we can easily get the operating frequency by it.

Since this is coherent algorithm and it require some prior knowledge of the signal which makes this algorithm more complicated in the term of hardware implementation and takes more time to sense the primary user.

3. PROPOSED HYBRID SENSING ALGORITHM

To increase accuracy and optimize the detection probability of cognitive radio user a hybrid sensing algorithms is proposed. Actually this algorithm is the cascading result of the Energy based sensing and Cyclostationary feature detection. From literature we know that energy based detection is simpler as compared to Cyclostationary feature detection. On the basis of this logic the output of the primary transmitter is allowed to pass first from Energy based detector and then from Cyclostationary feature detector. In this Hybrid sensing algorithm the energy based detector is used to verify whether primary user is present or not. Here Cyclostationary algorithm is used just to get the features (modulation, operating frequency, no. of signal) of primary user when primary is present and is used as detector when energy detector is not sure about the presence or absence of primary user. So this algorithm basically divides the tasks between Energy based detector and Cyclostationary feature detection. Actually the energy based detection is used as detector and Cyclostationary feature detection is used as feature extractor when primary user is present. This property of algorithm provides flexibility to switch to the tasks on need basis. The block diagram of this hybrid algorithm is shown below in figure 1.

Flow chart is also given in figure 2 from flow chart the output of the primary signal is first given to energy based detector. At this stage when the output of the detector is 1, it indicate the presence of primary user, then the features of signal is calculated by Cyclostationary feature extractor, when output is 0 this indicates that primary user is absent, also if the output is neither 0 nor 1 (N mean not sure) then energy detector pass this report to the Cyclostationary feature detector. The Cyclostationary feature detector reviews it and adjudicates primary user is present or not. When the output of Cyclostationary feature detector is 0 it indicates the absence of primary user but when its output is either 1 or >0 then it is considered as primary user is present.

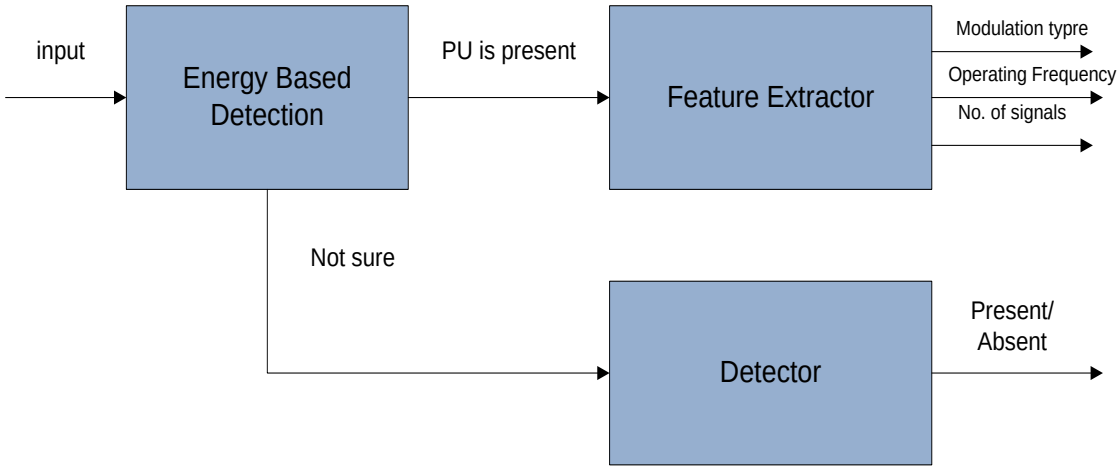

Fig 1: Block diagram of Hybrid sensing algorithm

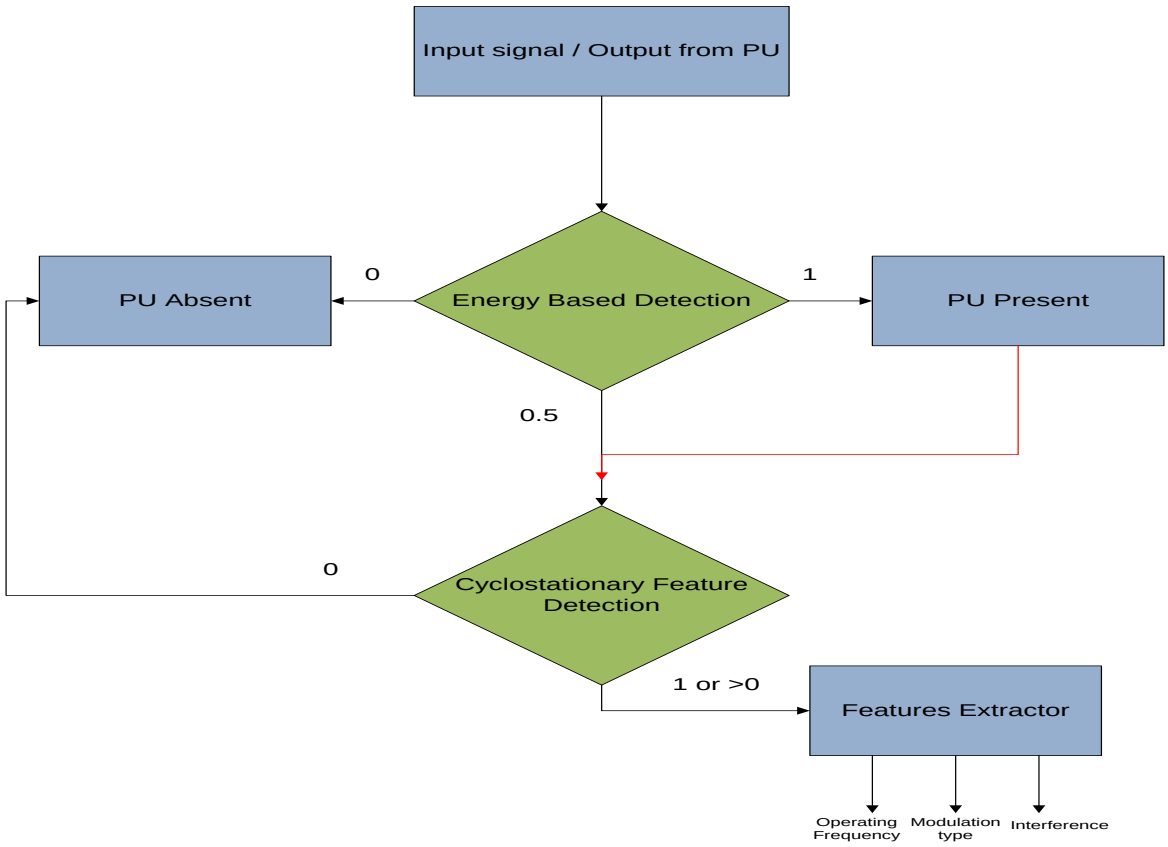

Fig 2: Flow chart of Hybrid sensing algorithm

4. RESULTS

From figure 3 it is clearer that if we see the mean square spectrum of energy detector we observed that there exist a peak value exactly at 4 KHz but from the figure a lot of peaks are also found so difficult to say exactly whether primary user is present or not. Any how this problem is completely sort out by Cyclostationary feature based algorithm and the figure clearly shows that the peak at 4 KHz is most dominant.

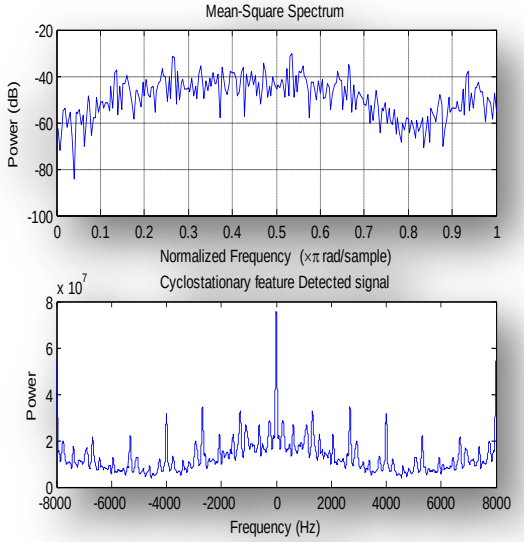

Figure 3 Outputs of the Energy Detector and Cyclostationary feature detector for 20dB SNR, 4 KHz frequency and BPSK modulation

Command Window's Layout
Energy detector output:
Primary user is present
Features Extracted by Cyclostationary feature detection of primary user are:
1. The operating frequency is
opf =
3.9995e+003
2. The modulation type is: BPSK
3. Interference: No interference

Similarly figure 4 shows that there exixt peak exactly at 4 KHz for energy based algorithm while there is not existing a dominant peak in case of cyclostationary feature algorithm.

So in this case when modulation scheme is QPSK it is good to choose the energy based sensing algorithm. So this clearly describe that primary user is present. In next step the features of primary user are extracted.

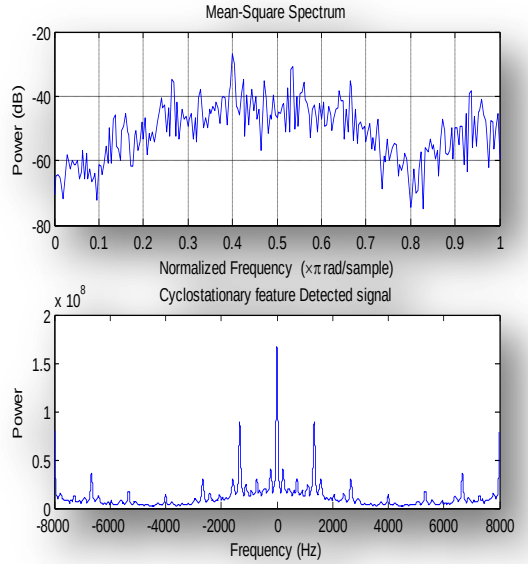

Figure 4 Outputs of the Energy Detector and Cyclostationary feature detector for 20dB SNR, 4 KHz frequency and QPSK modulation

Command Window's Layout
Energy detector output:
Primary user is present
Features Extracted by Cyclostationary feature detection of primary user are:
1. The operating frequency is
opf =
3.9995e+003
2. The modulation type is: QPSK
3. Interference: No interference

Figure 5 shows the result at low SNR and from the figure it is clearer that both the sensing algorithms fail to detect the presence of primary user. So we cannot extract the features of primary user. Thus in this case both algorithms are used as detectors.

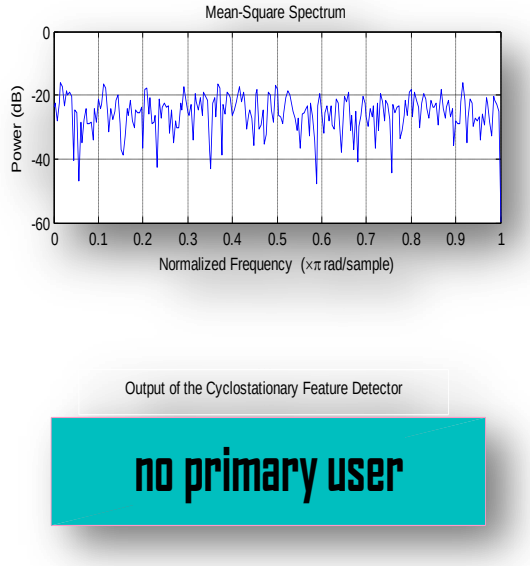

Figure 5 Outputs of the Energy Detector and Cyclostationary feature detector for -20dB SNR, 4 KHz frequency and BPSK modulation

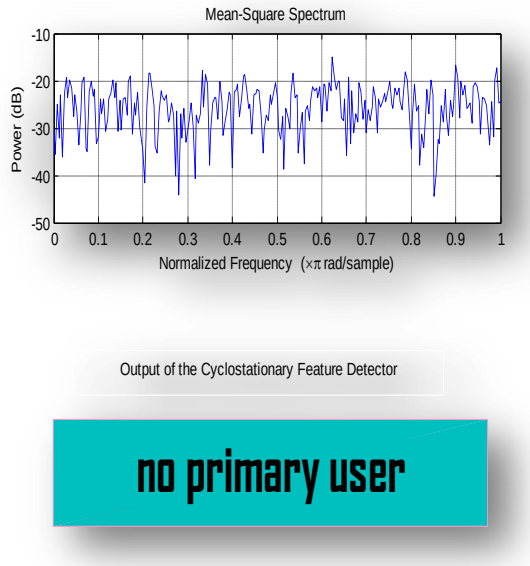

Figure 6 Outputs of the Energy Detector and Cyclostationary feature detector for -20dB SNR, 4 KHz frequency and QPSK.

Similarly figure 6 shows the results having low SNR value, thus figure is not giving a clear message whether primary user is present or not. Features of the primary user are not possible to be extracted and both the algorithms are acting as detectors.

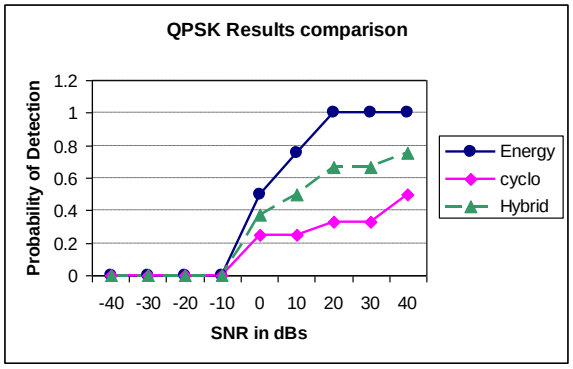

Figure 7 Comparison of three algorithms for QPSK modulation and under different SNR values.

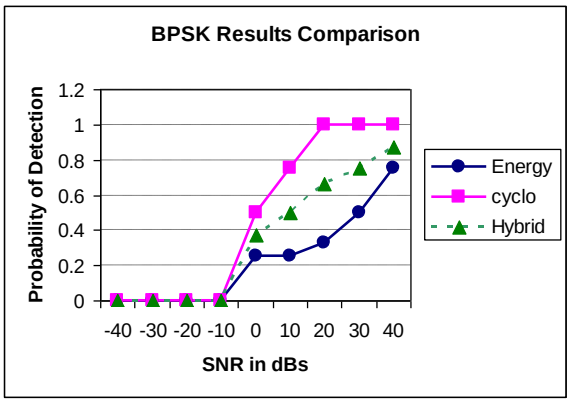

Figure 8 Comparison of three algorithms for BPSK modulation and under different SNR values.

5. CONCLUSION

Form the above results it can be concluded that Energy Based Detection gives very much clear results when modulation scheme is QPSK. However, the clearer results of Cyclostationary Feature Detection are possible when BPSK modulation is used. Our proposed algorithm gives the optimum results as compared to Cyclostationary feature detection algorithm and energy detection algorithm for both the modulation schemes.

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