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Boosted Energy Detector Based Spectrum Sensing Methodology For Cognitive Radio

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Abstract: Proliferation of spectrum-based service, in the recent years have forced the human society to become highly dependent on the radio spectrum. It is therefore not surprising that we are facing a difficult situation in wireless communications. Cognitive radio, a novel spectrum sensing paradigm, detects the presence of the user who has legal rights over the spectrum. This allows spectrum utilization by the primary user and in their absence the unused spectrum is allocated to the secondary user, thus potentially eliminating the limitation on wireless communication. In this paper, a simple spectrum sensing technique, energy detection method has been analyzed.The proposed work focuses on enhancing the performance of the energy detection technique by efficiently minimizing the sensing time required to find spectrum holes. This improved performance can be realized by replacing Fast Fourier Transform (FFT) with DWT. A new and novel method of fourth power of detection is performed unlike the conventional powers of operation and the ROC curve is plotted for various parameters. Multi Input Multi Output scheme can be incorporated so as to overcome the problem of noise uncertainty and to achieve good diversity. All these advances enhances the system performance, which results in reduced sensing time to detect the spectrum holes.

Key words: Cognitive radio · Spectrum Sensing · Energy detection · DWT · Fourth power detection · MIMO

INTRODUCTION

One of the main facets of modern day communication is the wireless communication. The various researches and analysis performed on it has taken this technology to a new level, which was unfathomable only a few decades ago. However, increased dependence on wireless communications these days have posed a severe problem of spectrum scarcity [1]. As a result, innovative techniques like cognitive radio are being employed as it makes a difference through a Dynamic Spectrum Access (DSA). Cognitive radio as such is defined as an environment-aware device which detects the availability of the spectrum and then allocates this band to the unauthorized user by varying its spectral characteristics accordingly [2]. The cognitive radio provides optimized local access of the spectrum in the realm of wireless radio devices. This technology senses whether the primary user, the one who has legal rights to access the spectrum, is present or not. Once it senses the absence of the primary user, the unused spectrum is now utilized by the secondary user [3].

Some of the main functions of cognitive radio are Spectrum sensing and analysis, Spectrum management, Spectrum allocation and sharing. Spectrum sensing in simple words, does the work of detection of the spectrum holes in a geographical area. It is considered as an essential part of cognitive radio [4]. Improper spectrum sensing results in collision between the primary and secondary user. This will end up in degradation of performance of cognitive radio as well as the primary user. For this purpose various sensors and beacons are employed. Once the bands are available for transmission, the frequency bands are shared among the users, so that there is no interference with the primary user [5]. Spectrum decision is used by the cognitive radio to determine the suitable spectrum band according to the requirement of the user and the characteristics of the spectrum. Spectrum mobility facilitates the cognitive radio to change its frequency band to the best available spectrum. Spectrum sharing provides spectrum scheduling so that there is no interference or collision among the users.

There are various methods of spectrum sensing namely energy detection, cyclostationary method,

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matched filter method [6]. Cyclostationary method requires prior knowledge about the frequency of the primary user [7] whereas matched filter requires knowledge about the channel of the primary user [8].

In this research contribution we deal with the energy detection method also known as transmitter detection. The energy detection technique also known as radiometry or periodogram,remainsthe simplest and prominent method of all because it has low computational complexities [9]. The receiver requires no prior data on the primary user's signal. In traditional energy detection methodthe analog signal is amplitude modulated in the transmitter side and sent over the channel. The received signal which is the combination of signal plus channel noise is pre-filtered and the analog output is digitized using analog to digital converter. The digitized signal is fed to the FFT block. FFT plays a vital role in analyzing the signals which do not have changes in their properties (stationary signal). It mainly computes in the frequency domain.

If the input is a non periodicsignal, the frequency spectrum which is obtained after taking FFT of the signal suffers from leakage. A window is a function which is designed to have zero value at the beginning and at the end of the interval and has some value within the interval. The output of the FFT is then multiplied with the window.This makes the signal periodic in nature and reduces the spectral leakage [10]. The windows does not eliminate the spectral leakage completely. They tend to reduce the spectral leakage. Each window has their own pros and cons. So the proper choice of the window becomes more vital. After windowing the signalundergoes traditional squaring and integration function. The processed output here is compared with the preset threshold value.Based on the two hypotheses decisions are made.

H0 = Only the presence of noise
H1 = Presence of both signal and noise

To enhance the performance of energy detection method the FFT is replaced with DWT. The various modern applications of wavelet theory are data compression, signal processing, image processing, detection of aircraft and submarine. The DWT has the advantage of minimum response time, low cost and greater flexibility [11, 12]. Wavelet is a short oscillating wave, comprising of window functions and analysis function. This wave oscillates and decays in a time domain. This short oscillatory wave with finite time extent is called discrete, where as the infinite extent is called continuous wavelet. The signal is decayed into high frequency components and low frequency components by passing the signal into corresponding filters respectively. The former gives accurate results and the latter provides approximate results. The process is repeated until the goal is reached.At the end the coefficients are summed up to yield the result [13].

Since the propagation channel in wireless communication is characterized by multipath propagation there results in SNR variations of the received signal. To overcome this MIMO technique has been employed. It is a wireless technology inwhich multiple transmitting and receiving antennas are utilized to transmit and receive the same data that has undergone fading in the channel. The receiver collects the data streams from individual antennas and best data integrity is achieved [14, 15].

Proposed Methodology: This block diagram of the offered method is as shown in Figure 1. In the proposed method enhancement of individual blocks is performed. Enhancement of the individual blocks will in turn improve the overall system performance.As a first step replacement of FFT is done by DWT. Then it is followed by proper choice of windowwhich avoids spectral leakage and further by taking fourth power of the magnitude instead of squaring the power to provide the energy enhancement could be achieved.

The analog signal is fed as the input to the transmitter which undergoes the amplitude modulation and the modulated wave is given by

$$x_{\text{mod}} = x_0 \,(1 + m_a \sin \omega_m t) \sin \omega_0 t \qquad (1)$$

where ω_0 is the carrier frequency and ω_m is the modulating frequency.

This modulated signal is then transmitted over the channel. The noise assumed here is additive white Gaussian noise (AWGN). The incoming signal is fed to the prefilter to filter out the unwanted noise components. Then it is given to the DWT block. Though Fourier transform is a powerful tool for spectral analysis it has bad convergency property and also the non availability of timely information made FFT a non-suitable candidate. DWT can be applied to analyze the non –stationary signals and local information areavailable in time domain. The multi resolution nature of wavelet makes it more appropriate to be utilized in this energy detection method.

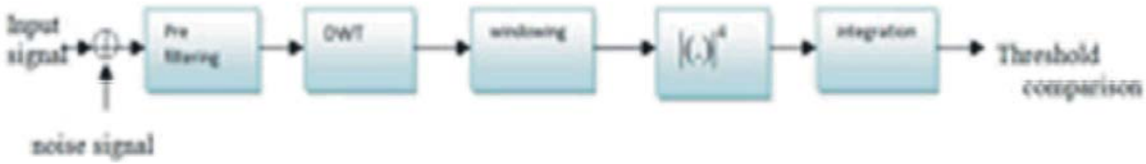

Fig. 1: Block diagram of the offered method

Since Windowing function greatly reduces the effect of leakage we make use of various windows, like Hamming, Hanning, Blackman, Kaiser windows and the comparative analysis of these windows is done along with the DWT.Hanning window is mainly used for random signals which provide best frequency resolution and accuracy. Hamming window hassimilar characteristics of the Hanning window. Kaiser window is the best when compared to the other since it provides better accuracy and resolution. It has less side lobes when compared to other windows. Blackman window performance is low when compared to other windows because it has a poor frequency resolution. The output of windowing is fed to the fourth power detector which enhances the performance of the detection method when compared to squaring operation.

The output of the proposed method is compared with the threshold. These hypotheses are analyzed by using Probability of detection , Probability of false alarm and Probability of missing detection. These probabilities are calculated as [16]

$$P_f = P[\lambda < v / H0] = \delta(m, v / 2) / \delta (m) \quad (2)$$

$$P_d = P[\lambda > v\ H_1] = Q_m\ (\sqrt{2\lambda}, \sqrt{v}) \quad (3)$$

$$p_m = 1 - p_d \quad (4)$$

where λ is the threshold

Optimization of threshold is the next way of reducing the sensing error which in turn enhances the system performance. In this research work two methods have been proposed to reduce the sensing error. To overcome problems of missed detection and false alarm in high noise scenarios the verdict about the existence of primary user is not decided based on a single hypothesis namely H_0 and H_1.The verdictabout the existence of the primary user is collected from N number of other secondary users who are located in our neighborhood. They sense the SNR of the same primary user and conclusions are made from the information collected from the N number of secondary users. By doing so the sensing error could be reduced to a great extent.

In this research work single transmit antenna and multiple receive antennas are utilized. The incoming signal from the primary user is received using multiple antennas and the average of the individual output is made. The average value is now compared with the threshold and decisions are made based on the hypotheses.

RESULTS AND DISCUSSION

The figures are plotted using MATLAB.Results are concluded from the ROC curves plotted for the energy detection method.

Figure 2 gives the comparison between the square, cubing and fourth powers of FFT and the fourth power of DWT. It is clear that DWT offers better result than FFT and further as the order increases,better results could be achieved because more information is available for processing.

Figure 3 gives a comparative study among various SNR values. From the figure it is clear that as the SNR increases probability of detection increases.

Figure 4 shows the comparative study plotted for various N values of Hanning window. Hanning window is chosen since it gives good frequency resolutions and gives moderate output for most of the applications. As the value of N increases probability of detection increases which in turn reduces the searching time for the free spectrum holes.

Figure 5 yields a comparison, plotted for various values windows. It is plotted using discrete wavelet transform and the fourth power of operation. From the figure it is clear Kaiser window offers better results than the other. As the value of beta increase there is an improvement in the system performance because with increase in beta the side lobe decreases.

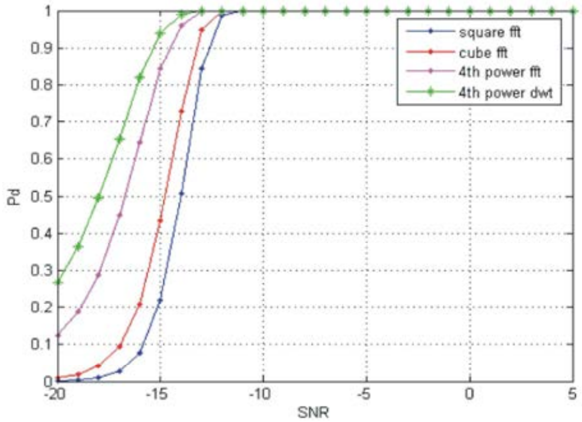

Fig. 2: Comparison between FFT and DWT

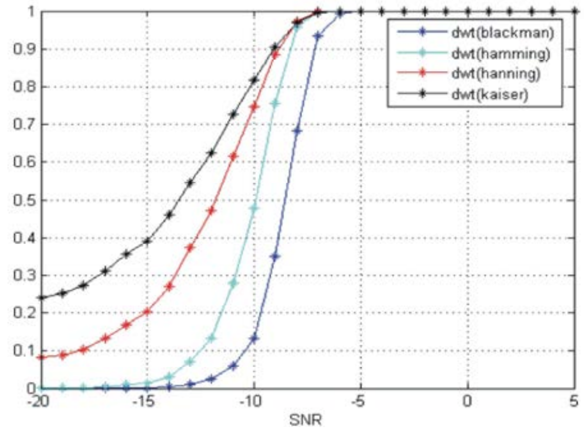

Fig. 5: Comparison between various windows

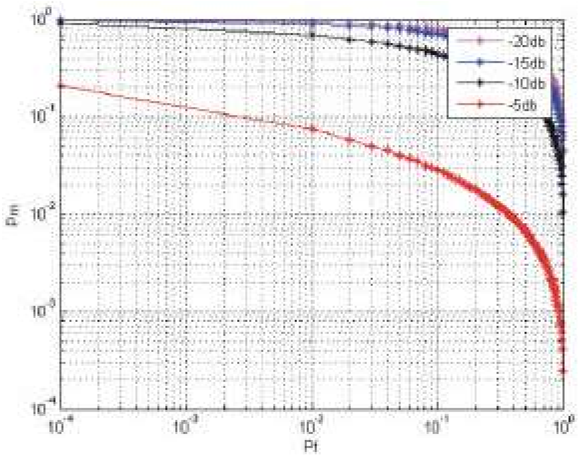

Fig. 3: Comparison between various SNR values

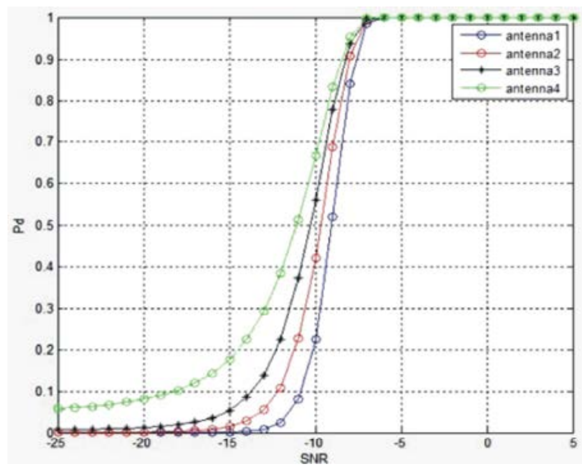

Fig. 6: Comparison between various antennas

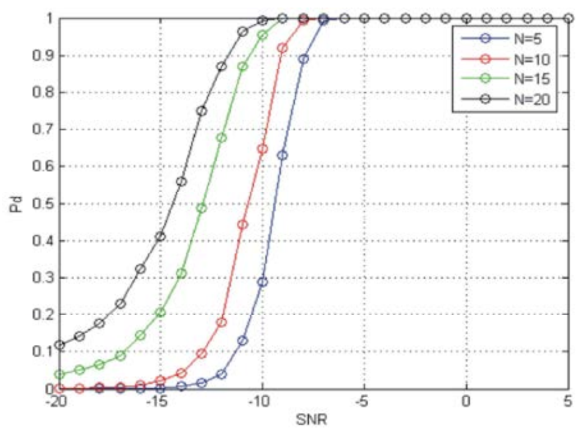

Fig. 4: Comparison between various values of N of Hanning window

Figure 6 gives a comparative analysis, among the primary user data received using many antennas. From the figure it is clear that Multi input multi output (MIMO) system over rules single input single output(SISO) system.

CONCLUSION

Spectrum sensing is the foremost part of the cognitivecycle. In this paper traditional energy based spectrum sensing is analyzed. The detection performance of energy detection method is enhanced by replacing FFT block by DWTNext, Kaiser window is chosen for carrying out the windowing operation and the squaring operation is altered bythe fourth power of operation. To further reduce the sensing error diversity scheme has been proposed.Simulations are performed by changing various parameters all which is meant for increasing the probability of detection.

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