# Cognitive Radio Spectrum Sensing: Discrete Wavelet Packet Decomposition based Energy Detection

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**Abstract- As the requirement of wireless communication services are growing, the demand of frequency resource is increasing. Cognitive radio proposed to solve the frequency scarcity started two decades before is now the key tool. The band width becomes expensive due to shortage of frequencies. Therefore to use the spectrum effectively, we need to identify whether the spectrum is occupied or not. Energy detection, Feature detection and Matched Filter detection are methods used for spectrum sensing. In this paper we have use Discrete Wavelet Packet Decomposition based Energy Detection (DWPDED) for sense the unused spectrum band in the RF spectrum. Simulation outcomes revels better results and fast sensing than the conventional method.**

**Keywords- Cognitive Radio, Spectrum sensing, DWPDED**

## I INTRODUCTION

It is observed that radio spectrum is scarce and precious natural resource but due to fixed spectrum allocation policies the spectrum is not utilized properly [1-3]. Cognitive Radio improves spectrum utilization efficiency by detecting free frequency spectrum and accessing licensed spectrum effectively [4-6]. The task of detecting vacant frequency band is done by sensing of radio spectrum accurately for efficient and effective utilization of radio spectrum even under fading condition [7-9]. False detection may cause harmful interference to licensed users. Thus there is need to design a spectrum sensing algorithm that can solve the problem of false detection even under fading condition [3, 5, 7, 10-11].

## II DISCRETE WAVELET PACKET DECOMPOSITION

Spectrum sensing is the major issue which is responsible for identifying the unused bandwidth and making it useful to the secondary users. There are numerous methods adopted for spectrum sensing based on frequency, time, geographic area etc [4-5]. One of the effective spectrums sensing method is energy detection [8]. We have used discrete wavelet decomposition based energy detection. We use two channel filter banks which divide the given signal into the low frequency component a(n) and high frequency component d(n) is employed. The use of high pass and low pass filter eliminates the lower half and the upper half frequency components, respectively. Which results that output signal only spans the half of the frequency band spanned by the total received signal. To maintain equal number of samples, the filter outputs are down sampled by factor 2. Therefore, level-1 decomposition process consisting of half band filtering and down sampling basically reduces the time resolution by a half and reduces the frequency band spanned by the signal by half as well. The scheme is then repeated successively on the obtained signal until the desired degree of resolution is achieved. In discrete wavelet packet decomposition based energy detection the two channel filter banks are utilized in frequency domain. Fig.1 which shows the level 1 decomposition in which signal is passed through filters and the output point of each filter is a wavelet packet nodes.

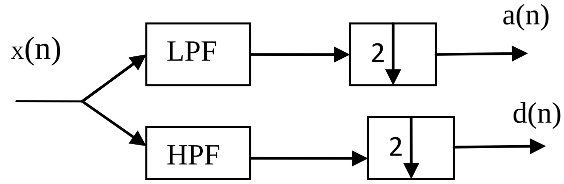

Figure 1 Level-1 Discrete wavelet packet decomposition

The greater the level of decomposition, the better the frequency resolution is achieved which is shown in Fig.2 level 2 decomposition.

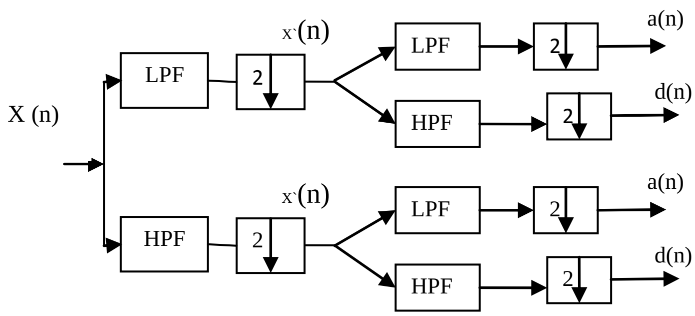


Figure 2 Level-2 Discrete Wavelet Packet Decomposition

## III. SYSTEM ASSUMPTIONS IN DWPDED

For Simulation following assumptions were taken.

- Frequency modulated signal with carrier frequency of 88Mhz, frequency deviation 75Khz and signal frequency 15KHz
- Amplitude modulated signal with carrier frequency 535KHz, signal frequency 15KHz
- Arbitrary signal of 350 KHz.
- Transmitted signals are received at Cognitive radio receiver with addition of noise**.**
- Primary user signal is transmitted through Rayleigh fading channel

## IV. ALGORITHM

Proposed algorithm for Simulation

- Firstly we identify primary users.
- Transmit different primary users signal through noisy channel or Rayleigh fading channel.
- Now start spectrum sensing of desired wideband frequency band.
- Perform discrete wavelet packet decomposition up to required resolution.
- Determine high and low frequency coefficients corresponding to terminal node.
- Rearrange the terminal node in order of increasing frequency band order.
- Calculate sub-band power corresponding to terminal node's coefficient.
- Compare calculated sub-band power with threshold
- Then decide whether sub-band is occupied or not.

## V. SIMULATION AND PERFORMANCE ANALYSIS

To implement the method in simulation environment, the proposed discrete wavelet packet decomposition based energy detection is implement and obtained results is compared with the conventional method based on multi filter based energy detection under low signal to noise ratio and under Rayleigh fading channel.

### *5.1 Simulation Model Analysis-*

For simulation, three signals transmitted by different primary users are generated. One of primary user signal is frequency modulated signal with carrier frequency of 88MHz, frequency deviation 75KHz and modulating signal frequency 15KHz.Another is an amplitude modulated signal with carrier frequency 535KHz and modulating signal frequency 15KHz. Third primary user signal is assumed to be arbitrary sinusoidal signal with message frequency 350KHz. These three signals are received at cognitive radio receiver with addition of random noise. This noisy mix signal is passed through a filter bank consist of four different band pass filter of 0-250 KHz, 250-500 KHz,500-750 KHz and 750-1000 KHz .Then average power of filtered output is calculated in individual frequency band and compared with threshold. In all simulation we assumed value of threshold is 50mw, i.e. if calculated average power in that particular frequency band is greater than threshold value then primary user is present in that frequency band otherwise primary user is absent thus that frequency band can be utilized by cognitive radio for signal transmission.

*5.2 Performance Analysis Multi-Filter Based Energy Detection Method under Low SNR-*

Under Low SNR, three primary users are not detected correctly due to addition of random noise to the signal, and false detection of the Primary user results Table 1 shows the received signal power after passing through different filter bands. Under low SNR, it shows that signal power received by passing signal through first filter band of 0- 250 KHz was less than the threshold, that means that primary user was free and not using its frequency.

Table- 1 Status of the Frequency band under low SNR

| Multi-filter Based Energy Detection Under Low SNR | | | | |
|---|---|---|---|---|
| S no | Frequency Band | Filtered Signal Power (mw) | Threshold (mw) | Status of the Frequency Band |
| 1 | 0-250KHz | 0.121 | 50 | Frequency band Available |
| 2 | 250-500KHz | 189.66 | 50 | Primary user signal was present |
| 3 | 500-750KHz | 337.17 | 50 | Primary user signal was present |
| 4 | 750-1000KHz | 426.74 | 50 | Primary user signal was present |

The graphical representation of the received power is shown in fig 3 which shows that the signal passes through the filter having bandwidth 0-250 kHz

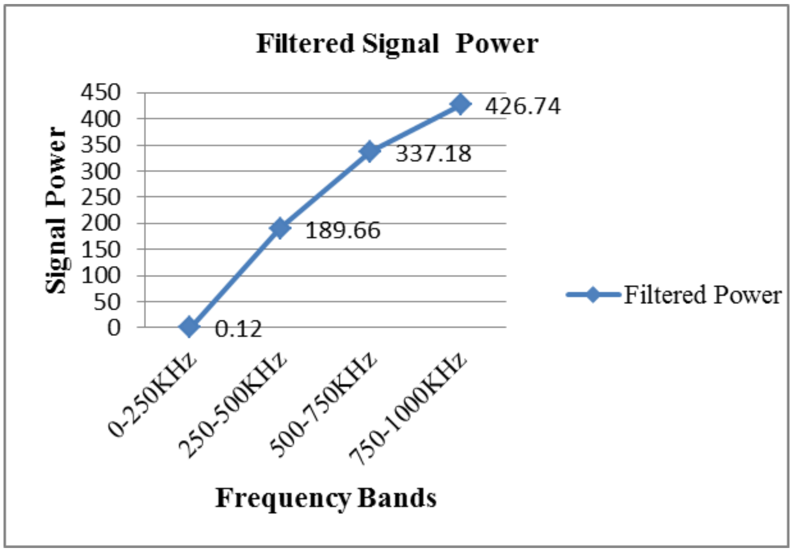


Figure 3 Graphical Representation of received Filter Power under Low SNR.

*5.3 Performance Analysis of Discrete Wavelet Packet Decomposition based Energy Detection under Low Signal to Noise Ratio.*

Using the proposed discrete wavelet packet decomposition based energy detection algorithm under low signal to noise ratio it yields that the obtained signal power in all the four nodes is greater than the threshold value of 50 mw.

Table – 2 Status of the Frequency band under low SNR

| Nodes | Energy | Power | Status of Frequency band | Time |
|---|---|---|---|---|
| Node 0 | 0.049 | 245.09 | Primary user Present | 0.002001 |
| Node 1 | 0.106 | 53.56 | Primary user Present | 0.002001 |
| Node 2 | 0.138 | 69.18 | Primary user Present | 0.002 |
| Node 3 | 0.184 | 92.044 | Primary user Present | 0.002001 |

Figure 4 shows the graphical representation of the obtained result for the proposed algorithm all the nodes has average power greater than the threshold value, thus yields the correct detection of all the frequency bands under low signal to noise ratio.

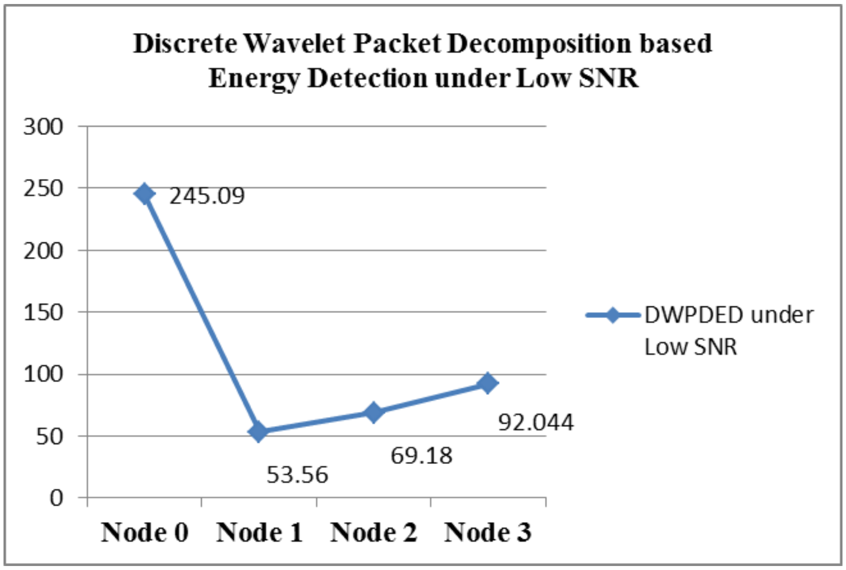


Figure 4 Graphical Representation of received Signal Power using Discrete Wavelet Packet Decomposition based Energy Detection under low SNR

*5.4 Simulation model of primary user detection with Rayleigh fading using multi-filter based energy detection*

Table- 3 shown that under Rayleigh fading without Doppler shift faded noisy primary user signal is received at CR receiver, is processed through multi-filter based energy detector. In first iteration primary user's signal in 0-250 KH, 500-750 KHz and 750-1000 KHz frequency band, have average power greater than threshold value 50. Detect primary users in three frequency band of 0-250 KHz, 500-750 KHz and 750-1000 KHz band thus produces correct result in this band while produces false detection in other frequency band of 250-500 KHz. In second iteration it produces false detection in three bands and only one correct detection in band 500-750. In third iteration it produces correct result in 3 bands and false detection in 1 band. In fourth iteration it produces correct result in 2 bands and false detection in remaining 2 bands. In fifth iteration it produces correct result in all 4 bands. In sixth iteration it produces correct result in 2 bands and false detection in 2 band. In seventh iteration it produces correct result in 3 bands and false detection in 1 band.

Table – 3 Performance of Multi-Filter Based Energy Detector Under Rayleigh Fading

| Frequency Band (KHz) | Iteration | Power (mw) | Status of Primary user |
|---|---|---|---|
| 0-250 | I | 125.57 | Primary User was present |
| | **II** | **24.82** | **Primary User was Absent** |
| | III | 641.59 | Primary User was present |
| | IV | 337.47 | Primary User was present |
| | V | 112.25 | Primary User was present |
| | VI | 536.10 | Primary User was present |
| | VII | 204.55 | Primary User was present |
| 250-500 | **I** | **31.03** | **Primary User was Absent** |
| | **II** | **11.40** | **Primary User was Absent** |
| | III | 90.30 | Primary User was present |
| | **IV** | **21.37** | **Primary User was Absent** |

| | | | |
|---|---|---|---|
| | V | 115.06 | Primary User was present |
| | **VI** | **21.13** | **Primary User was Absent** |
| | **VII** | **26.76** | **Primary User was Absent** |
| 500-750 | I | 518.58 | Primary User was present |
| | II | 72.45 | Primary User was present |
| | **III** | **40.63** | **Primary User was Absent** |
| | IV | 83.13 | Primary User was present |
| | V | 66.92 | Primary User was present |
| | **VI** | **33.22** | **Primary User was Absent** |
| | VII | 71.86 | Primary User was present |
| 750-1000 | I | 802.86 | Primary User was present |
| | **II** | **45.6** | **Primary User was Absent** |
| | **III** | **40.96** | **Primary User was Absent** |
| | IV | 52.96 | Primary User was present |
| | V | 96.34 | Primary User was present |
| | VI | 101.40 | Primary User was present |
| | VII | 69.51 | Primary User was present |

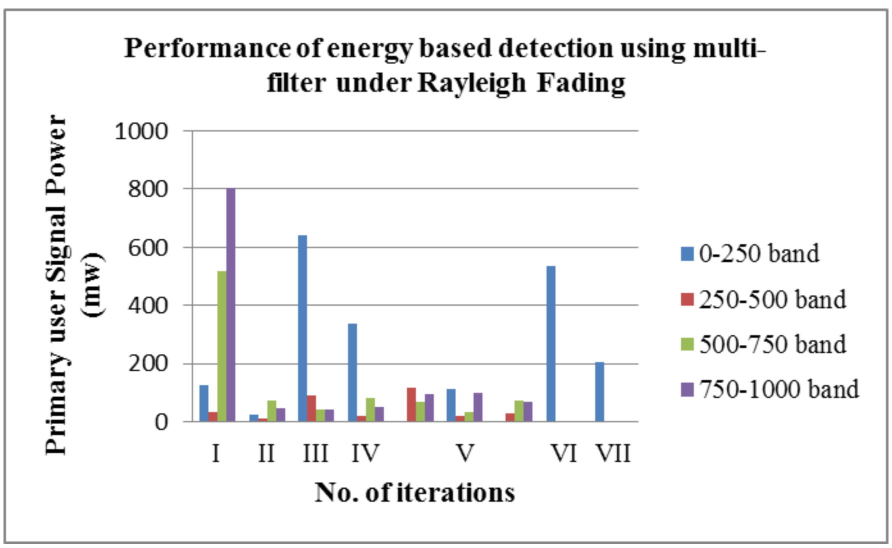


Figure 5 Performance of energy based detection using multi-filter under Rayleigh Fading without Doppler shift

*5.4 Performance Analysis of Discrete Wavelet Packet Decomposition based Energy Detection under Rayleigh Fading.*

For obtaining the better performance index when signal passes through Rayleigh fading channel, VII iteration is done. Table 4 shows the performance analysis of DWPDED under Rayleigh channel which shows the existence of the primary user based on the obtained signal power. In first iteration all four frequency band is detected. In second iteration one band is detected correctly. In third and fourth two bands is detected correctly. In fifth and sixth iteration all the four bands is correctly detected and in seventh only three frequency bands is correctly detected.

Table- 4 Performance of DWPDED under Rayleigh Fading

| Frequency Band (KHz) | Iteration | Power (mw) | Discrete Wavelet Packet Decomposition Based Energy Detector |
|---|---|---|---|
| 0-250 | I | 134.15 | Primary User was Present |
| | **II** | **27.42** | **Primary User was Absent** |
| | III | 640.07 | Primary User was Present |
| | IV | 332.96 | Primary User was Present |
| | V | 109.09 | Primary User was Present |
| | VI | 532.62 | Primary User was Present |
| | VII | 198.63 | Primary User was Present |
| 250-500 | I | 54.70 | Primary User was Present |
| | **II** | **12.6** | **Primary User was Absent** |
| | III | 139.78 | Primary User was Present |
| | IV | 50.05 | Primary User was Present |
| | V | 122.43 | Primary User was Present |
| | VI | 67.14 | Primary User was Present |
| | **VII** | **46.88** | **Primary User was Absent** |
| 500-750 | I | 555.25 | Primary User was Present |
| | **II** | **34.42** | **Primary User was Absent** |
| | **III** | **48.18** | **Primary User was Absent** |
| | **IV** | **34.41** | **Primary User was Absent** |
| | V | 76.39 | Primary User was Present |
| | VI | 68.56 | Primary User was Present |
| | VII | 100.42 | Primary User was Present |
| 750-1000 | I | 805.6 | Primary User was Present |
| | II | 51.77 | Primary User was Present |
| | **III** | **59.06** | **Primary User was Absent** |
| | **IV** | **42.86** | **Primary User was Absent** |
| | V | 96.83 | Primary User was Present |
| | VI | 100.42 | Primary User was Present |
| | VII | 58.46 | Primary User was Present |

Fig 5 shows the performance analysis of the obtained signal power in each iteration, it is noted that using proposed technique the probability of correct detection of the primary user is increased.

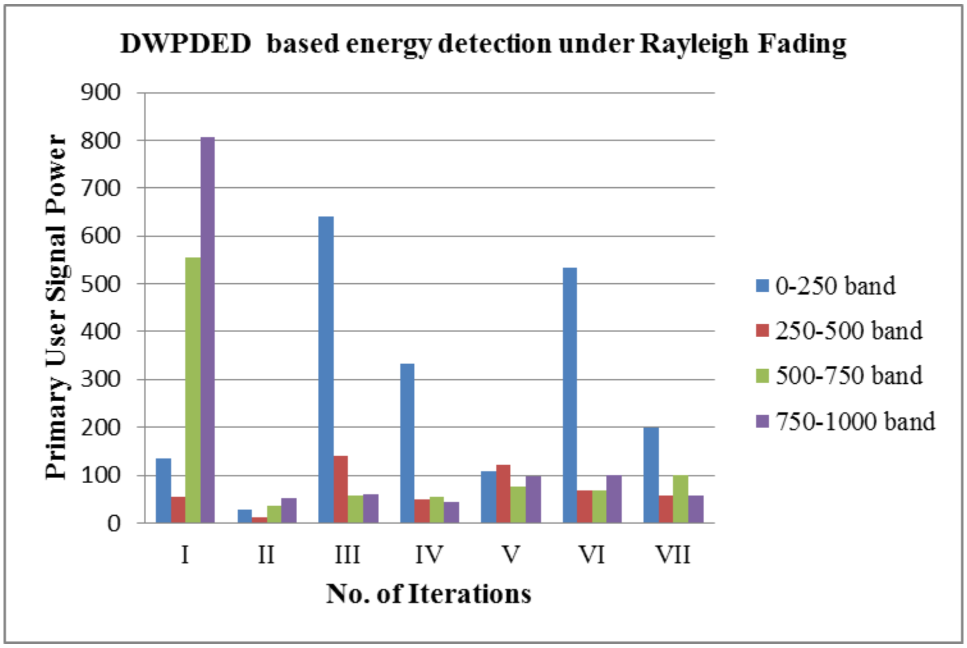


Figure 5 Representation of received Signal Power using Discrete Wavelet Packet Decomposition based Energy Detection under Rayleigh Fading.

## VI. RESULT ANALYSIS

Fig 6 shows the comparative analysis for each iteration for the multi filter and proposed algorithm. In first iteration all the four frequency bands is correctly detected by using the proposed technique, while only one frequency band is correctly detected by using Multi filter based energy detection. In second Iteration only one frequency band is correctly detected by discrete wavelet packet decomposition based energy detection and two is detected by multi filter based energy detection. In third iteration only two are correctly detected by proposed technique and multi filter based energy detection. In fourth iteration two bands by discrete wavelet packet decomposition based energy detection and four by multi filter based energy detection. In fifth and sixth iteration again four bands is correctly detected by DWPDED and again only two is correctly detected by Multi filter based Energy Detection. The overall performance of discrete wavelet packet decomposition based energy detection is better than multi filter based energy detection.

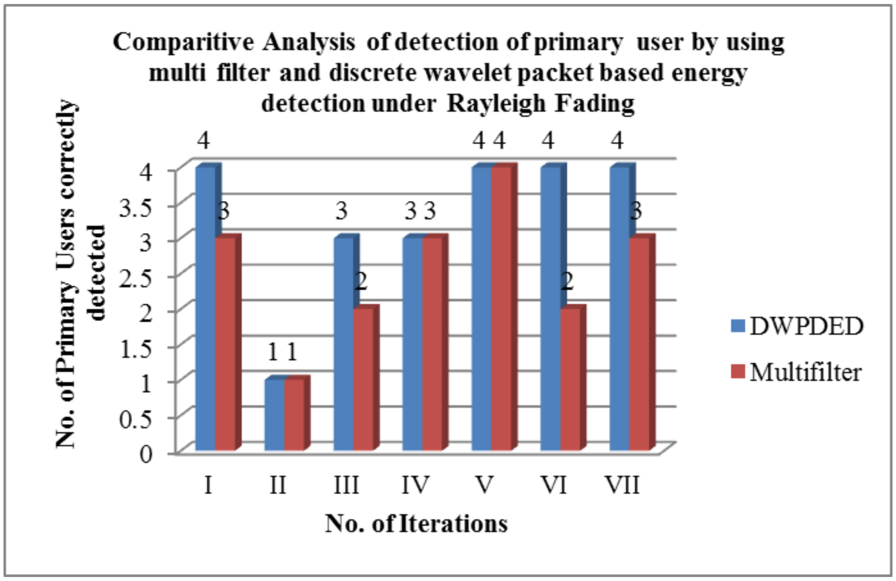


Figure 6 Comparative study of performance evaluation based on energy detection by discrete wavelet packet decomposition based energy detection and multi filter based energy detection.

## VII CONCLUSION

Cognitive radio is emerging technology to solve the problem of spectrum under utilization and improve spectral efficiency along with communication quality. This technology has become an exciting and promising concept in resource constrained wireless sensor network. Under low SNR energy detector based on multiple filters produces false detection while proposed algorithm discrete wavelet packet decomposition based energy detection produces correct result. Simulation results show that under Rayleigh fading with discrete wavelet packet decomposition based energy detector spectrum sensing method detects primary user more accurately than the energy detector based on multi-filter. Therefore, the wireless communication systems that are established in areas where spectrum is allocated to primary users which have exclusive right to access that licensed spectrum have low spectrum utilization factor, cognitive radio network using discrete wavelet packet decomposition based energy detection method of spectrum sensing can optimally sense available frequency spectrum more reliably and consistently than other spectrum sensing techniques such as simple energy detection method and multi filter based energy detector.

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