Comparative Analysis and Hybrid Modeling of Spectrum Sensing in COGNITIVE RADIOS

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ABSTRACT

Rapid growth of wireless applications and services has made it essential to address spectrum scarcity problem. In this context, an emerging technology, cognitive radio (CR) has been come out to solve this spectrum scarcity problem. The most important function of cognitive radio is spectrum sensing which requires more accuracy & low complexity. This paper proposes spectrum sensing technique using Wavelet Packet Transform (WPT) based energy detector. Among its fundamental functions, the most important function is spectrum sensing which requires precise accuracy and low complexity. Thus, in this paper, the fast spectrum sensing algorithm using the discrete wavelet transform (DWT) and Fast Fourier Transform (FFT) filtering schemes is proposed. By simulations and complexity analysis, it is verified that the proposed algorithm achieved better results than traditional ones.

Keywords: Cognitive Radio, Wavelet Packet Transform, Discrete Wavelet Transform, Fast Fourier Transform, Spectrum Sensing.

I. Introduction

The radio frequency spectrum is limited resource. As the technology is improving, higher amount of data is needed to be transferred. For this, the bandwidth requirement is increasing exponentially. Currently a large portion of licensed bandwidth is not being used most of the time due to the user requirement and geographical problem. The cognitive radio is the technology that can reach the bandwidth requirement. Cognitive Radio enables most of the radio frequency spectrum to be used at a time

The basic principle of cognitive radio is to detect whether the primary (licensed) user is using its allocated bandwidth or not. Whenever the primary user is not using his bandwidth, cognitive radio enables the secondary user to use that bandwidth. If the primary user wants to use his allocated bandwidth, the cognitive radio has to free its bandwidth by changing the secondary user to another bandwidth[1]. This process should be done in such a way that there shouldn't be any interference between Primary User (PU) and Secondary User (SU).

The cognitive radio has three functions: spectrum sensing, spectrum analysis and spectrum decision making. Researchers have proposed several methods for detection of primary user. Some of the methods are energy detection (ED), waveform detection (WD), matched filtering detection (MFD), Radio identification based (RID) and cyclo-stationary feature detection (CFD)[2] . The Energy detection method is least complex method, requires minimum computation and can be easily implemented, hence commonly used for spectrum sensing. The main problem with energy detection (ED) is the deterioration of detection performance in case of fluctuating unknown noise power. In this method, the knowledge of primary user's signal is not required at the receiver for detection. The signal is detected by comparing the output of energy detector with a threshold which depends upon the noise. The important challenge is the selection of threshold for detection of primary signal.

The probability of detection (PD) varies with the change in different pa. The purpose of the paper is to generate an algorithm for energy detection with the use of wavelet packet transform for noise power estimation. The result of the algorithm (Probability of Detection) with unknown noise is compared with the expected probability of detection with known noise. Different parameters (number of samples, Probability of false alarm, wavelet function, decomposition level of Wavelet Packet Transform) are varied and its effect on the Probability of Detection is observed.

The cognitive radio is future changing technology. This technology has very high impact on all industries where data is transferred i.e. all communication based industry, military, medical industry etc. the Cognitive radio can enable high bit rate data transfer for most of the users without any interruption[3][4].

II. System Model

Spectrum Utilization for Cognitive Radio

Once the nonexistence of a primary user signal, through spectrum sensing, has been established in a given spectrum band, Cognitive Radio users are permitted to activate in the band as extended as they adjust transmission parameters to keep away from objectionable intervention with licensed users while ensuring proper signal reception . The performance of the CR users and the interference with the licensed users need to be well balanced in spectrum utilization.

Spectrum Shaping

Orthogonal FrequencyDivision Multiplexing (OFDM) is an impressive broadcast technique for Cognitive Radio as it allows turning off tones to openly avoid licensed users as well as supports adaptation to radio environment and obtainable resources. Momentarily, with Orthogonal Frequency-Division Multiple Access (OFDMA) like the several access method, Cognitive Radio users can employ non-adjacent sub-bands through dynamic spectrum aggregation to maintain elevated data range . Accessible spectrum estimation methods have been classified into time-domain as well as incidence field approaches. It is inherent that an elevated cosine window can be applied to the time domain pulse to hold down OOB radiation. However system throughput is decreased in the windowing technique as extension of symbol duration is required to check Inter-Symbol Interference (ISI). An additional time-domain technique at the expense of throughput decrease is adaptive symbol transition which puts in extensions between orthogonal frequency-division multiplexing symbols. In the frequency domain, an effortless tone-mulling method disables orthogonal frequency-division multiplexing subcarriers at the edges of the used frequency band with the most important effect on the OOB discharge in bands right next to each other. Furthermore, active intervention termination has been described in through connecting withdrawing tones adaptively on the edges. It facilitates deeper spectrum indentation although the computation is concentrated on the transmitter. Likewise, subcarrier weighting , multiple-choice series , as well as preferred mapping are specified to contain OOB emission on the basis of transmitted data.

Resource Allocation

Cognitive Radio users regulate their transmission parameters by resource allocation to achieve distinct management necessities and understand effectual interference monitoring. Due to the subsistence of certified users as well as potential common interference among two different classes of users, the task of resource allocation for opportunistic spectrum consumption in CRNs is not equivalent to that of current wireless networks. Usually, a Cognitive Radio user is able to broadcast for an extended time as the interference to the licensed user is under a predefined threshold. The most common controls to protect LUs are peak and average interference power constraints.

III. PROPOSED SYSTEM

Spectrum Analysis

In the unlikely event that some individual is gathering, illustrating or included in field organization/repair of electrical schemas or contraptions, he/she needs a gadget which will help in analyzing the electrical signals that are passing through or being transmitted by the structure. When you are done with it, you can know the execution, search for issues, troubleshoot, etc.

By what technique might we have the capacity to measure those electrical signals to see what happens to the signals as they pass through the device and therefore check the performance. All we need is a confined beneficiary, which doesn't do anything to the signal - it fundamentally reveals to it in such a course, to the point that makes it less requesting to grasp and explore the signal. This is known as a spectrum analyzer. Spectrum analyzers show unrefined, characteristic signal information, for instance, power, voltage, wave shape, period, sidebands, frequency et cetera. They give an acceptable as could be and definite window in the frequency spectrum.

Considering the order, a signal can have unique perspectives. Case in point, in correspondences, remembering the final objective to send information, for instance, some individual's voice or data, it must be tweaked into a higher frequency transporter. A managed signal has particular properties depending upon the sort of modulation used. Exactly when testing non-straight devices, for instance, blenders or speakers, it is must to perceive how those make distortion things and what those distortion things appear like. Catching the characteristics of noise and how a noise signal appears diverged from others help us in breaking down our device/schema.

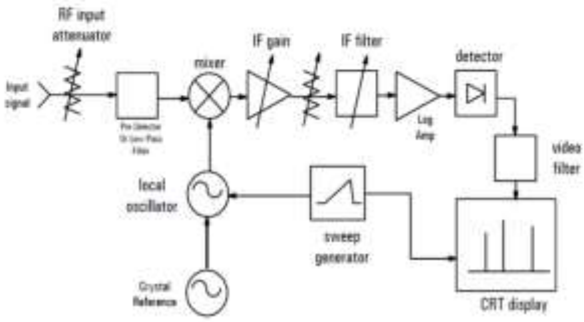

Fig: 1. Spectrum Analyzers (SA)

WAVELETS

Wavelet analysis is a new development in the area of applied mathematics. Wavelets are now emerging as one of the fastest growing field with application ranging from seismology to astrophysics. One of the most significant developments is the realization that, in addition to the canonical tool of representing a function by its Fourier series, there is a different representation more adapted to certain problems in data compression, noise removal, pattern classification and fast scientific computation. Wavelet packets are increasingly being used in sparse representation of signals, though it deviate from classical wavelet theory in which a signal is finally expressed in terms of dilated and translated version of a single wavelet function.

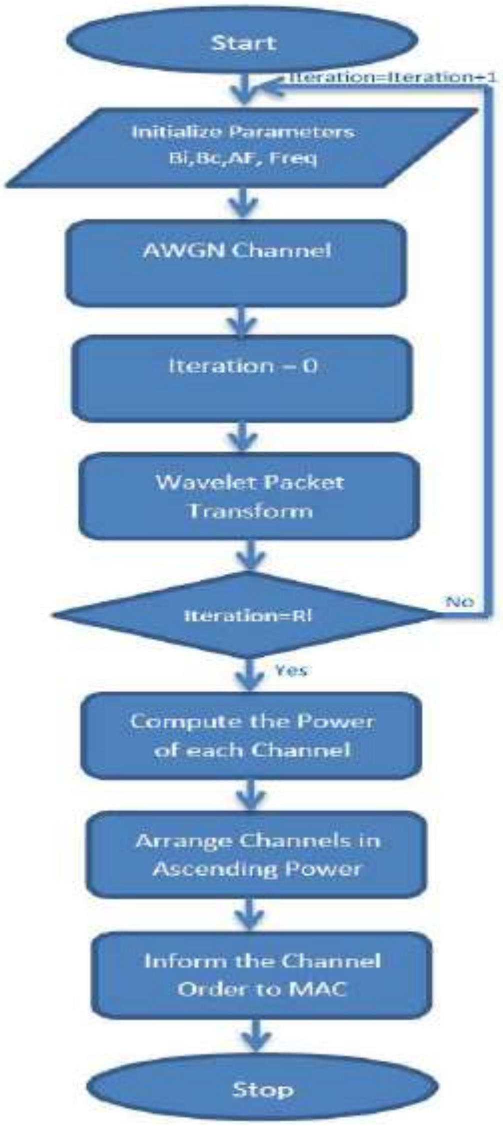

Fig: 2. Proposed Flowchart

WAVELET PACKET TRANSFORM

Wavelet transform is well suited for identification of information in low-frequency band but not suitable for identification of information in high-frequency band. The wavelet packet transform (WPT) has the ability to identify information in low frequency bands as well as high frequency bands. The WPT has higher frequency resolution and lower time resolution at low-frequency while it has higher time resolution and lower frequency resolution at high frequency[5]. Thus, WPT is ideal tool for processing of nonstationary time-variable signal.

For most application, a low frequency signal is used for communication and it contains noise signal of high frequency. To separate the noise signal from interested signal, the wavelet transform decomposition is used. It divides the signal into two coefficients, the approximation coefficients of low frequency and the details coefficients of high frequency.

$$S=AAA_3+DAA_3+ADA_3+DDA_3+AAD_3+DAD_3+ADD_3+DDD_3 \qquad (1)$$

Wavelet Packet Transform

As an extension of the standard wavelets, wavelet packet represent a generalization of multi-resolution analysis and use the entire family of subband decomposition to generate an over complete representation of signals (Soman and Ramachandran 2005). Wavelet decomposition uses the fact that it is possible to resolve high frequency components within a small time window, while only low frequency components need large time windows. This is because a low frequency component completes a cycle in a large time interval whereas a high frequency component completes a cycle in a much shorter interval. Therefore, slow varying components can only be identified over long time intervals but fast varying components can be identified over short time intervals. Wavelet decomposition can be regarded as a continuous time wavelet decomposition sampled at different frequencies at every level or scale. The wavelet decomposition functions at level m and time location tm can be expressed as

$$d_m(t_m) = x(t)\psi_m (t-t_m/2^m) \qquad (2)$$

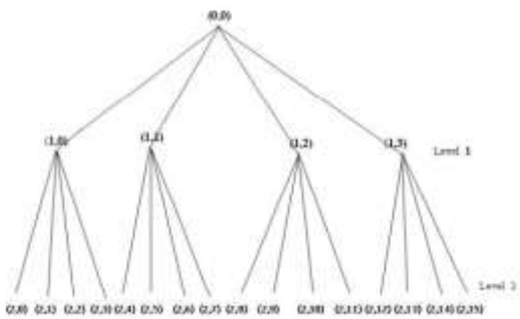

Fig: 3 Wavelet Packet Transform

Wavelet Based Spectrum Sensing in Cognitive Radio

Cognitive Radio is an intellectual radio having the ability of recognizing the vacant spectrum to transmit the data to avoid spectrum inefficiently usage problem. b) Here CR uses the spectrum policies technique, to spot the existence of user in particular frequency band. c) In this paper, for efficient spectrum sensing operation, a Wavelet and S-Transform based approach for the detection of sub band edges in wide spectrum band where primary users are available. The S-Transform (ST), is a hybrid of the Short Time Fourier Transform and Wavelet transform, has a time frequency resolution which is far from ideal. For time-frequency representation the ST is known for its local spectral phase properties. Here the exact occupation of primary users and noise signal is calculated by STransform.

Discrete wavelet transforms is the most popular transformation technique adopted for image compression. So the proposed methodology of this paper is to achieve high compression ratio in images through implementing Haar Wavelet Transform and daubachies wavelet transform using software tools MATLAB. Through experimental results we compare performance of both the transforms. We works in the MATLAB computing environment, the Wavelet Toolbox offers some significant advantages. The amount of information retained by an image after compression and decompression is known as the energy retained, and this is proportional to the sum of the squares of the pixel values. If the energy retained is 100% then the compression is known as lossless. This occurs when the threshold value is set to zero, meaning that the detail has not been changed. If any values are changed then energy will be lost and this is known as lossy compression. Ideally, during compression the no of zeros and the energy retention will be as high as possible. However, as more zeros are obtained more energy is lost, so a balance between the two needs to be found.

Discrete Wavelet Based Spectrum Sensing

The Wavelet Series is only a sampled version of CWT hence its computation may take significant amount of time and resources, depending on the resolution required. For fast computation of Wavelet Transform, Discrete Wavelet Transform (DWT) yields better result w easy and reduces the computation time and resources required. Same technique as sub-band coding was developed which was named pyramidal coding. Later these coding schemes were improvised which resulted in efficient multi-resolution analysis schemes.

Discrete Wavelet Packet Transform

a) Current spectrum management model, command-and control, is creating a fundamental cause to drop the spectral efficiency of the radio spectrums in times and spaces.

b) An emerging technology, cognitive radio (CR) has been come out to solve today's spectrum scarcity problem. Among its fundamental functions, the most important function is spectrum sensing which requires precise accuracy and low complexity.

c) Thus, in this paper, they proposed the fast spectrum sensing algorithm using the discrete wavelet packet transform (DWPT) and infinite impulse response (IIR) polyphase filtering schemes. Explanation: Wavelet Analysis and Power Measurements- Construction of the wavelet transform and understanding of wavelet basis are provided by the multiresolution analysis [6]. In addition, the efficient hierarchical algorithm for computing the wavelet transform is in the filter bank theory [7].

In the developing world, the usage of Mobile phones and other data communication devices are unavoidable which results in the congestion of Spectrum. Recent studies have showed that nearly 70% of spectrum was unused most of the time. Cognitive Radio is a technology which helps us to use the spectrum effectively. Spectrum Sensing is one of the techniques in cognitive radio. Energy detection, Feature detection and Matched Filter detection are methods used for spectrum sensing. The proposed method, Discrete Wavelet Transform (DWT) is used to identify the unused spectrum band in the RF spectrum. This will yield better results and fast sensing than the conventional method.

Algorithm for Spectrum Sensing in CRN

Input : $A_i, j, s_{j,} c_j, c_i, \alpha_i^{(l)}, \beta_i^{(l)}$ **% Base station Location**

Output : $\alpha_i^{(l+1)}, \beta_i^{(l+1)}, s_i, A_i$ % spectrum Allocation

$\mathcal{A} = \{m: [A_i]_{m,1} = j\}$ % *previous bits*
if $A == 0$ **(3)** , $Test = false$ % no $previous\ bits$

else $m = max\{n : n€A\}$

if $S_j > [A_i]_{m,2}$

else $m = max\{n : [A_i]_{n,1} = j\}$ % complete bits updated

$\alpha_i^{(l+1)} = \alpha_i^{(l)} (\omega_R + \omega_T K)$

$\beta_i^{(l+1)} = \omega_T(c_j - Kc_i) + \beta_i^{(l)}(\omega_R + \omega_T K)$ **(4)**

From (4), $A_i = j, s_j, c_j, c_i$ % Space Multiplexing

IV. Experimental Results

Since cognitive radios come to the implementation phase already, we have to address the implementation considerations that have been recently investigated. The main factors that enable efficient and optimized implementation is to provide the smallest power consumption, the highest network throughput which is mainly affected by the sensing cycles, a feasible complexity for the target technology. While all these factors are optimized, the system performance has been carefully investigated to measure the loss in performance due to the implementation challenges. In very specific scenarios, there may be additional considerations for the system to be realized. For example, if cooperative sensing is employed, the control channel parameters have to be optimized as well. In fact, comparisons between conventional sensing approaches have been presented in more than one research activity. However, these efforts have not considered the recent advances to spectrum sensing with the presented deep classifications. In this section, we present the most important considerations including the power consumption, the sensing interval, the complexity, the impact of implementation on performance, and some other system specific considerations.

Complexity

The complexity and computational power is the most sensitive aspect from implementation perspective. The reason is that complex algorithms many not be feasible for implementation or they might be feasible but not efficient from power consumption and delay perspectives. In this regard, massive proposals from research have been recently presented to tackle the complexity issues. The proposals either present enhancements to existing algorithms or new techniques that reduce the complexity when compared to conventional ones. In this section, we present the most interesting proposals in both directions to highlight the complexity issue. Due to the well-known detection performance limitations for energy detectors, an improved version of the energy detection algorithm is presented and evaluated. Results show that this technique is able to outperform the classical energy detection scheme while preserving a similar level of complexity. In max-min approach is presented to detect signal energy under selective fading and uncertainty conditions. A justified complexity reduction by 78% is the main objective of this proposed approach. Under timing misalignment from various PUs at the CR receiver, a generalized likelihood ratio test is utilized in along with energy detection to not only estimate the time differences but also to sense the presence of the PUs.

Sensing Interval

In fact, increasing the sensing period has the impact of reducing the overall cognitive network throughput. Therefore, this parameter has to be carefully considered with the same importance as the power budget. There have been research efforts which attempt to minimize the time duration for spectrum sensing by jointly optimizing the sensing time with the detection threshold. The PU throughput statistics are considered to protect the PU while the sensing time is minimized. Motivated by the fact that high false alarm rates require the sensing cycle to be more frequent, an enhanced quiet-period management scheme has been reduce the sensing interval. The technique utilizes multiple sensing approaches to reduce the sensing interval. The idea is that a feature detector is employed if an energy detector constantly issues false alarms for a predefined number of times. Recently, an analytical model has been presented to optimize the sensing interval based on a satisfactory measure which accounts for the missed transmission opportunities if the current state is busy, the transmission collisions to the PU if the current state is idle, the decreased or increased throughput and possible interference to the PU caused by the delayed spectrum sensing. The effect of imperfect sensing performance on the optimized sensing interval is investigated. From the primary user perspective, the effect of sensing time and interval on the interference ratio (equivalently, the probability of collision) has been studied. The optimal sensing time and interval achieving maximum throughput for secondary users while satisfying the required interference ratio are also derived. Following this study, several proposals to realize this protection have been presented. Other efforts try to coordinate between the primary user requirements and the optimized sensing interval. For example, divide the PU band into two sub-bands, one for opportunistic SU data transmission, and the other for continuous spectrum sensing. Based on the PU band division, a delay oriented continuous spectrum sensing scheme is presented for delay sensitive SU services.

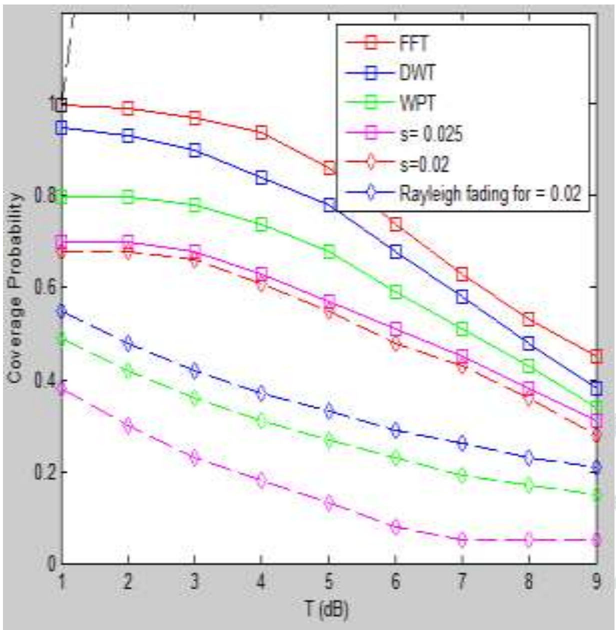

Fig :4. coverage Probability vs Time (debauches) with fixed threshold

In figure 4 Assigning threshold value with in the average of various techniques like FFT, DWT, WPT. Giving a certain fading value for WPT, DWT and FFT as 0.02, 0.02, 0.025 respectively.

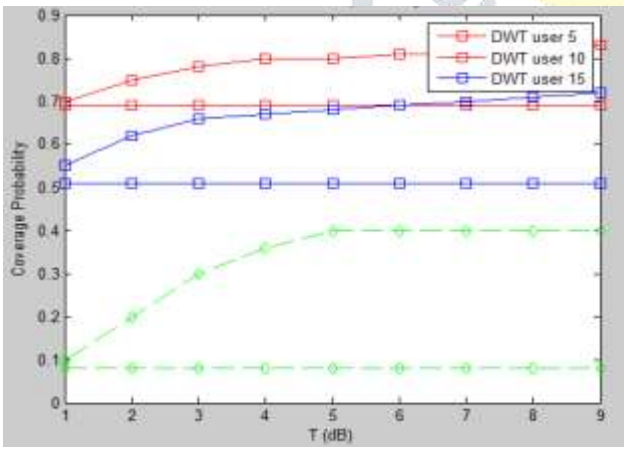

Fig: 5. different users transmitted in coverage range vs Time

In figure 5 Different users like user 5, user 10, user 15 transmitted in coverage area with respect to time is plotted. calculation of losses in miss detected areas in available space.

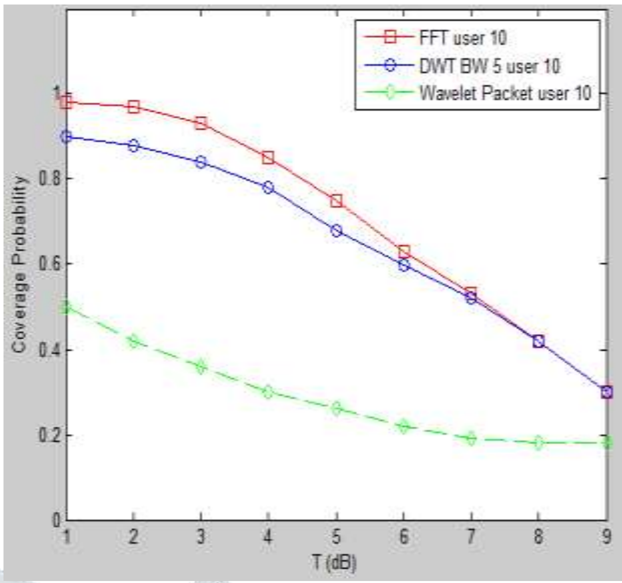

Fig :6. users transmitted in FFT,DWT,WPT within coverage range

In figure 6 shows the detection probability of various energy detectors. Transmission of users upto 10 in WPT, DWT and FFT only for miss detected areas.

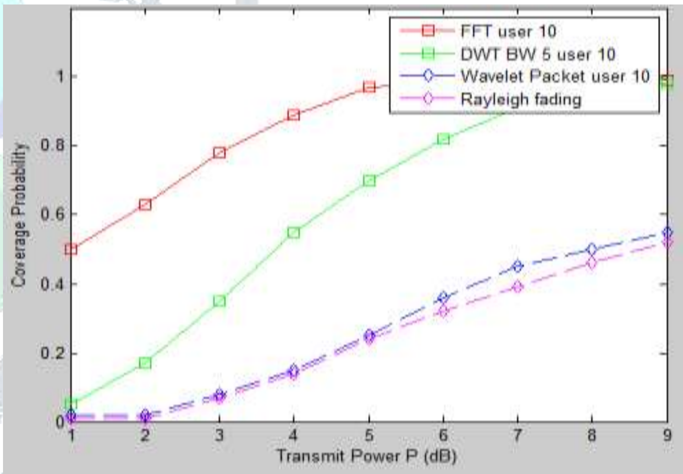

Fig: 7.transmit Power VS coverage probability

In figure 7 shows the transmitted number of channels among FFT based detector, wavelet packets and proposed DWT based energy detector

The final outputs for dwt & wpt cases, sorted channel indexes, are then further sent to the MAC for Spectrum Sharing to make CRN. Thus making possible for the proposed scheme select the unoccupied channel without confirming whether spectrums are unused or not and thereby making proposed scheme the Fastest and most efficient Sensing techniques for CRN.

V. CONCLUSION

The secondary spectrum has been issued due to its property that improves spectra efficiency. In this context, CR has received a plenty of attentions and one of the its critical technologies is spectrum sensing which requires fast processing and precise accuracy not to interfere with licensed users. Thus, in this paper, the fast spectrum sensing algorithm based on DWPT is introduced focusing on the coarse sensing. Using the multi-resolution property of DWPT and two channel wavelet filter banks, the proposed algorithm has simple structure and reduces computational complexity comparing to the conventional schemes. Simulation results show that the proposed algorithm can sense surrounding environment. Therefore, it is concluded that the proposed scheme can be a possible energy detector for CR.

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