Optimization Scheme with Energy Detector Model for Cognitive Radio Networks

Dinokumar Kongkham, M Sundararajan

Abstract*: Cognitive Radio (CR) is a promising technology in the wireless communication system for resolving the resource utilization problems and spectral clogging problems in the spectrum based applications. It aims to enhance spectrum sharing scheme in Multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) to enable with next generation systems. Efficient utilization of Spectrum sensing and computational complexity is still an unsolved issue in the ultra-wide band (UWB) radio spectrum. Generally, conventional methods include spectrum sensing to identify the primary users and spectrum usage, which helps to make data transmission possible from secondary users. However, they obtain poor throughput, higher transmission power and longer sensing time. In order to resolve this issue, we propose novel hybrid access optimization scheme with energy detector model for achieving the significant compressive spectrum sensing in the MIMO-OFDM, which is based on cognitive ratio network (CRN). The proposed method develops sparsity signal model with the help of orthogonal transform of Fractional Fourier Transformation (FRFT) for reducing the signal to noise ratio (SNR). Furthermore, modulated signals from secondary users are forwarded to DSP (Digital signal Processing). Hence, the proposed system achieves higher accuracy in detecting the false probability, energy detection, optimal sensing time, and higher throughput than efficient compressive sensing method.

Index Terms*: Spectrum Sensing, Novel Hybrid Access Optimization scheme, Energy detector, Sparsity Signal Model and Fractional Fourier Transformation.

I. INTRODUCTION

Multiple Input Multiple Output (MIMO) scheme utilizes the frequency multiplexing for achieving efficient spectrum usage. Consistence with the MIMO technology and orthogonal frequency division multiple (OFDM) have been discovered as an encouraging solution for interfacing with broadband wireless networks to achieve the better performance over selective frequency channels. OFDM is also considered as essential element in the spectrum utilization, which can adjust each tones of orthogonal into other tones. Along with MIMO, OFDM have been accepted as the most developing wireless communication system like IEEE 802.20, IEEE 802.16e, and 3GPP long term evolution (LTE) of fourth generation system, specifically for mobile broadband system. On another side, due to ineffective methods and protocols have causes the overcrowding and over utilization of the radio-frequency bandwidth in wireless communication system [1].

Cognitive Radio (CR) has been introduced as an approach to advance the effective utilization of the spectrum holes. In CR, primary users have utilized spectrum time slots, which can also allocated resources to the secondary users [2]. At present, spectrum sensing have been developed to greater extend, in which set of frequencies bands are stacked, while rest of the signals are rarely utilized. Compressive Sensing (CS) [3] have been utilized for form a framework to obtain the receiver signal[4]. CS is a method, which allows compressed signals or sparse sampling signals for significantly reducing samples. As per the CS theories, a sparse signal is based on time discrete that can be exactly retrieved by certain amount of random matrix projection. Therefore, CS theory has been applied for minimizing the sampling rate in the ultra-wideband spectrum sensor, power-sensitive wireless communication system, and bandwidth limited sensor terminals.

In CR system, the SUs can discover whether the primary users have occupied the spectrum band or not, by using the spectrum holes. Moreover, SUs make use of the efficient spectrum utilization in the unoccupied spectrum bands for the data transmission [6]. Hence, these type of technology have been helpful for the performing basic process of the signal communication in the wireless system.

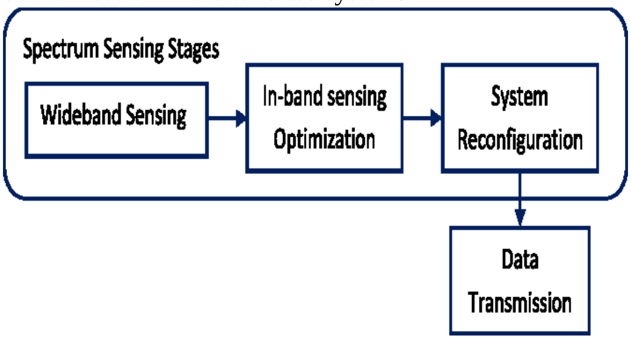

Fig.1 Spectrum Sensing Stages

The wideband sensing performs the process of the coarse sensing for identifying the specific channels by using the spectrum hole, whereas sensitivity is not taken as important concern in the communication network. The basic process of discovering the channel depends on the length and availability of the bandwidth obtained by the channel state transition using estimation algorithm [7]. The efficient sensing process is referred as in-band sensing, that performed when an identified opportunity is applied by the secondary user (SU). To extend the signal protection for the primary user (PU) as well as to obtain optimal results from SUs are based on the efficient spectrum sensing [4], [5]. We assumed that SUs are performing within a fixed time frame model, which comprises of sub carriers in the data transmission and the sensing time frames. Thus, it is very essential to design the optimization method, which provides tradeoff between data transmission and the sensing time period with higher throughput.

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Although, so many authors have discussed about sensing time, computational complexity, but have not compared with different optimization algorithms. Moreover, studies on system performances are depend on real experimental data, which is still lacking.

In this paper, we propose novel hybrid access optimization scheme with energy detector model for achieving the significant compressive spectrum sensing in the MIMO-OFDM based on cognitive ratio network (CRN). The proposed method have developed sparsity signal model with orthogonal transform of Fractional Fourier Transformation (FRFT) in order to reduce the signal to noise ratio (SNR) and then sampled signals from SU are modulated to DSP (Digital signal Processing) to achieve the higher performance.

II. LITERATURE REVIEW

Various spectrum sensing schemes had been reviewed in the literature, which was divided into two sets: wideband spectrum sensing (WSS) and narrow- band spectrum sensing (NSS) [8] and [9]. The throughput of the spectrum sensing has become tradeoff issues, which was formulated in [10], to enhance the SUs throughput under the various limitation of detection probability. The author [11] has proposed cooperative sensing for the spatial diversity in the dynamic wireless communication system. However, the author had concentrated on the NSS, in which SU can only access and sense the channel within a given time slot. The main drawback of this method was substantial overhead issues in the multiple channels.

Certain authors has worked on the spectrum sensing methods, they have provided advantages and their drawbacks in [12]. The author[13]proposed a two-stage spectrum sensing scheme in order to enhance the sensing time and decrease the energy consumption, which was performed at the first stage. In the next stage, coarse sensing process has failed to reduce the noise signal. The author [14] has enhanced the sensing performance via a two-stage two-bit CSS and the author [15] had minimized energy consumption using two-stage energy-efficient with one bit CSS, but they lacking with optimization technique.

In the same manner, the author [16] had investigated about the detection thresholds value and sensing time, which was combined together for optimal solution [17] as to enhance throughput of the aggregate from the SUs. During interference with the primary users in the network, which was under restricted level to carry out the further communication with SUs? In [18], the transmission power and the sensing time of the specific channel was optimized under the various circumstances of transmission power with the restrictions and power constraints. However, all of these previous methods have not concentrated on the reducing the noise ratio and detecting the energy from the SUs.

III. RESEARCH METHODOLOGY

System Model

In the system model of the cognitive radio network (CRN), wideband spectrum sensing is primarily considered for selecting a wireless channel. In this methodology section, we consider a MIMO-OFDM based on CRN by exploiting spare signal sensing model. At the beginning, we consider primary users (PU) and its transmission antennas T_{PU} in the MIMO system. We also believed that subcarriers T_{SC} considered for data transmission would send the sparse signal with finite numbers of sub carriers to each antenna. We have certain number of active sub carriers $T_{SC'}$ in the MIMO system. Then, we assume that secondary users have occurred in the receiving stage. After the spectrum hallow is found, then significant sensing is performed in the second stage. The sensing or in band is carried out with significant spectrum sensing for protection of primary users (PU). During the reconstructing process or figuring out the signals, which have been transmitted from the PU to the receiving antenna. SU can estimate the set of active sub carriers frequencies required for the retrieving information from the spectrum usage. With respectively to the conventional methods of MIMO-OFDM receiver, the received signal always has certain set of random sequence, which is generated from the receiver antenna. Then complete modulated and received signals are combined together with the help of ADC (Analog to Digital Signal convertor) to recover the signal, but it obtains the poor throughput and higher sensing time. Therefore, to overcome this issues, we propose the novel hybrid access optimization algorithm with sparse random measurement for significant compressive spectrum sensing for MIMO-OFDM based CRN.

The main objective of this paper is to obtain the optimization results for the sensing time and the higher throughput with minimum transmission power for the secondary users. The proposed method can handle optimization problems and provide the access to all the channels with lesser complexity. Hence, it designed to provide optimal sensing time as well as protect the primary users and predefined frame duration are proceeded under different signal to noise ratio conditions.

We assumed that SU system have inhabited with a bunch of overlapping PU channels. These channels are formed as the wideband spectrum in the CRN and the total number of channels is denoted as N. Let the probability condition for the first hypothesis is given as H_0, in the probability channel n. Then SU system is associated with base station and various SUs .The processing unit of SU system is classified into two section; spectrum sensing section and transmission section. During the spectrum sensing process, the PU are sensed by the base stations, through wideband spectrum sensing in the uplink situation, in which BS provides the exact states of the each channel whether it lies in the idle or active. In the transmission section, the secondary users forwards the data transmission to the base station through MIMO-OFDM technique that automatically adjust the power, depend on the sensing result, which is required for the data transmission. If the channel n is sensed then power of the transmission would be $\lambda_n P$ where λ_n is referred as power control elements.

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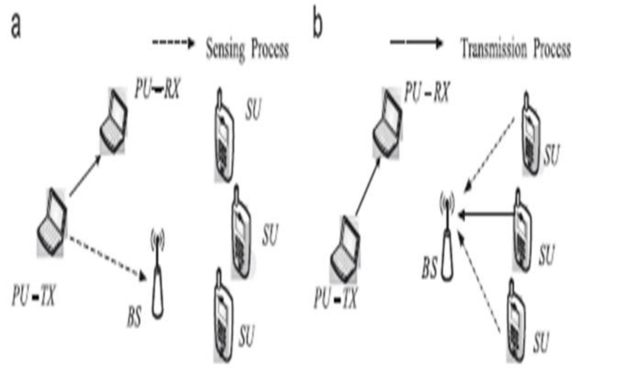

Fig.2 System Model

The selected channel occupied by the secondary users with data frame structure is demonstrated in Fig.2. The sensing duration is referred as t_s and the complete time frame duration is denoted as T.

The sensing process is performed at the starting slot of the data frame to access the status of the channel, whether it is idle or active. When the channel remains idle, SU would forward the intermediate data frame to the specific receiver. At the end of the data frame, when PU is identified, then SU would provide the secure data transmission in order to protect the PU from the harmful signal interference. On the hand, if PU is not identified, frequency band would be once again handled by the SU in the upcoming frame, which repeats the process unstill it finds PU. However, it consumers higher sensing time and lower performance in the CRN, whereas it obtains the poor quality of service (QoS).

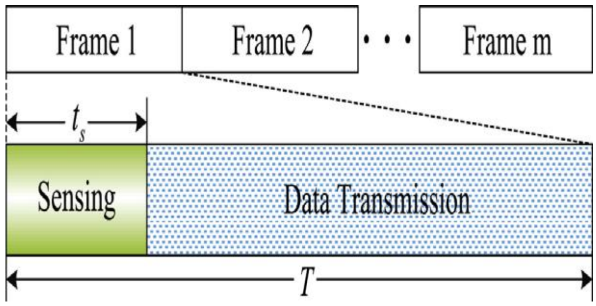

Fig.3 Time frame

The SU with sensed signal have provided with two hypotheses cases such as [15]:

$H_0 : R[n] = W[n]$, if PU is not available

$H_1 : R[n] = hS[n] + W[n]$, if PU is available

Where, n=1,…M, where M is considered as the total number of samples and h represents gain of the channel under the both hypothesis. The W[n] refers to the noise of the signals, which is considered to the complex Gaussian distribution [16]. Whereas the S[n] denotes to PU signal that considered for the random matrix. In practice, this SNR estimation is computed from test statistics of the real sensed data and stores in the knowledge database to facilitate the two stages of sensing.

Sparse Random Measurement Signal

Several antennas at the receiver side, in conventional MIMO-OFDM system is assumed that consumes high power for the multiple ADC circuits, which have been utilized in the system. Therefore, we propose sparse random measurement signal model for the MIMO-OFDM depend CRN method. Rather than using simple ADC on the individual's antenna, the received and modulated signals are combined with a single DSP, where

$$Y_r = \sum_{j=1}^{N_s} d_j Y_j^r \qquad (1)$$

In this process, Y_j^r represents for the symbol for the receiving signal on the jth antenna and d_j is consider as vector, in which each antenna can modulate the signal from the receiving side before sampled by the DSP. Generally, we will choose a pseudo-random distribution sequence to adjust the noise error occurring at the receiving signals for every antenna present in the transmission section. Moreover, it is also considered as friendly to the hardware model. In this proposed system, we use the orthonormal transformation to reduce the noise in the receiving signal, which also apply the sparse random measurement matrix for the generating random sequences. It can combine all the modulated signals to the energy model based DSP

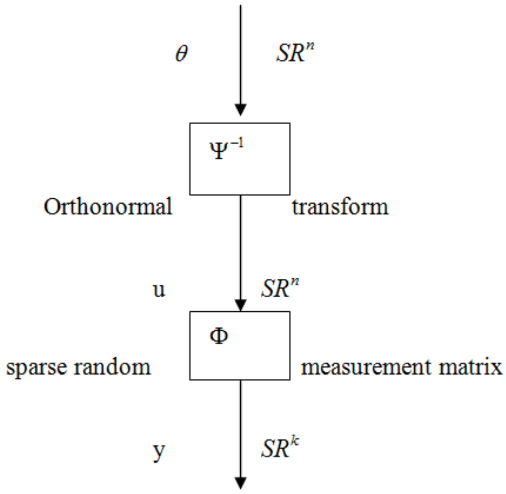

Fig.4 Sparse random Measurement Signal

We assume antenna at both end transmission and sensing side, would evaluate about the original signal vector $v \in \mathbb{R}^{n\times n}$ comprising of a set of orthonormal basis vectors $\{\Psi_1, \ldots.., \Psi_n\}$. Ψ Is denotes the vectors. We consider that obtained values have sparse representation in Fractional Fourier Transformation (FRFT). The orthonormal transformation coefficients is represented as $\theta = [\Psi_1^T v, \ldots.., \Psi_n^T v]^T$ of the original signal can be placed in the magnitude of $|\theta|_{(1)} \geq |\theta|_{(2)} \geq \ldots. \geq |\theta|_{(n)}$. The exact k-term approximation maintains the greatest k transform coefficients and considers rest of the value as zero. The approximation error in the signal was represented as:

$$\| v - \hat{v} \| \frac{2}{2} = \| \theta - \hat{\theta} \| \frac{2}{2} = \sum_{i=k+1}^{n} |\theta|_{(i)}^2 \quad (2)$$

We conclude that the signal would be able to compress, if suppose the magnitude of its transform coefficients decay like the energy law. By utilizing this matrix, overall the transmission cost is reduced and furthermore energy consumption is lesser, which is added to the DSP block.

The value of M is influenced by number of samples N of PU and the sparsity stage of the original signal. Then it transmits the signal to the base node in M rounds, which is associated to the SU to the base node. Considering all the modulated signals are transformed using FRFT in the sparse random measurement matrix ϕ, which is the total sum of the sub carriers present with their frequencies from the SUs. When the base receives all the M rounds of sampled signals from the PU, original signal can retrieved at the SU using approximate sparse random measurement signal

Therefore the sampling and receiving process are mathematical expressed in the below equations:

$$Y^r = Hx + \Psi + E_s \quad (3)$$

Where Ψ represents to the orthogonal vector used for reducing the noise signal, then H denotes the sparse random matrix used for the channel estimation and E_s is referred as the statistic energy detector, which is explained be Y^r =H $\begin{bmatrix} F_{\alpha_{Nf}} & 0 & \dots & 0 \\ 0 & F_{\alpha_{Nf}} & \dots & \dots \\ \dots & \dots & \dots & 0 \\ 0 & \dots & 0 & F_{\alpha_{Nf}} \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ \dots \\ b_{Ns} \end{bmatrix}$ + $\Psi + E_s$

(4)

$$Y^r = \text{DH} \begin{bmatrix} F_{\alpha_{Nf}} & 0 & \dots & 0 \\ 0 & F_{\alpha_{Nf}} & \dots & \dots \\ \dots & \dots & \dots & 0 \\ 0 & \dots & 0 & F_{\alpha_{Nf}} \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ \dots \\ b_{Ns} \end{bmatrix} + \begin{bmatrix} \Psi v_1 \\ \Psi v_2 \\ \dots \\ \Psi v_{Ns} \end{bmatrix} +$$

$$\frac{1}{T_s} \sum_{n=1}^{Ts} [v_i(n)]^2 \quad (5)$$

Where $E_s = \frac{1}{T_s} \sum_{n=1}^{Ts} [v_i(n)]^2$

$$= \text{DH}\, F_\alpha + \Psi + E_s \quad (6)$$

$$= \text{A} + \Psi + E_s \quad (7)$$

Where Ψ represents the for the dimensional noise deduction in the sparse measurement signal with finite number of non-zero elements. Then F_α stands for FRFT matrix, it is an integral transform with time fractional domain of *Nf*. Since the ith antenna transmitted over the OFDM system including the concatenation operation, which is represented as b_i. Apart from these sensing matrix is determined as

A = DH F_α **(8)**

Hence, our proposed achieves in detecting the sub carriers b using the sensing matrix from the sampled signals. In the upcoming section, we propose the hybrid access optimization scheme.

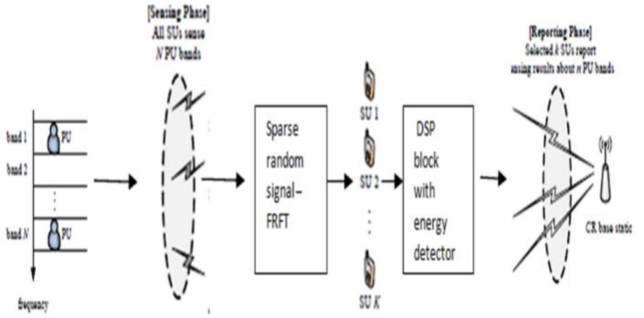

Fig.5 Proposed System Diagram

Novel Hybrid Access Optimization Scheme

To achieve optimal global sensing time for the MIMO-OFDM based CRN networks, it is basically depend upon the sensing time R(x), and sensing time (Ts) and the probability of the false alarm (Pd). The proposed system can enhance the spectrum usage and reduce the sensing time as well as gradually increases the achievable throughput. In this process, we deal with energy detector and the fusion model under fixed frame period for resolving the optimization problems in CRN. Each SU utilizes the individual decision and then transmits the to the common channel. Let us consider Φ represents the number of the SUs with reporting time duration of the PU. In this proposed, overall decision factor scheme would be derived from the randomized rule.

If $\Phi > k$, decide H_1

If $\Phi = K$, decide H_1 with probability $\alpha (0 \le \alpha \le 1)$

If $\Phi < K$, decide H_0

Here, K stands for the integer, and k=1,2,….,N is the final decision factor with global threshold value, which is obtained from the central limit theorem [13]. Our motive is to get the optimal k value to enhance spectrum usage with minimum transmission power. For reporting the transmission channels, we estimate the detection probability and the false alarm probability

$$O_d = \sum_{i=k+1}^{N} \binom{N}{i} P_d^i (1-P_d)^{N-i} + \alpha \binom{N}{k} P_d^k (1-P_d)^{N-k}$$

(9)

$$O_f = \sum_{i=k+1}^{N} \binom{N}{i} P_f^i (1-P_f)^{N-i} + \alpha \binom{N}{k} P_f^k (1-P_f)^{N-k}$$

(10)

The Circularly Symmetric Complex Gaussian (CSCG) process is used to reduce the noise obtained from modulated signal of SU, and mathematical model is designed to provide the optimal sensing time, which yields higher achievable throughput for the MIMO-OFDM based CRN.

$$R(x) = \left(1 - \frac{T_s}{T_f}\right)\left(1 - P_f\right) \quad (11)$$

Where

$$T_s = \left(\frac{0.9}{SNR^2}\right)\left(O^{-1}(P_f)\right) - \left(O^{-1}(P_d)\right) \times \sqrt{(2SNR+1)}^2)$$

[12]

Depend on the experimental settings for the sampling time, frame period, and sensing time and target probability of detection of 90%, would provide the optimal value of T_s to resolve optimization formulation in the CRN.

In CRN networks, wideband spectrum sensing should voluntarily accept the configuration parameters to the dynamic performance environment. For this cause, the optimization methods are designed in light weight manner with enhanced throughput and accuracy. This proposed concept utilizes orthogonal transformation to obtain the sparse random signal using the FRFT transformation. Then modulated signal from the SU are passed to DSP block with energy detector to protect the PU.

IV. RESULTS AND DISCUSSION

In our proposed method, for the performance analysis of the energy detection, detection spectrum usage and optimization algorithm are implemented using the MATLAB under the different SNR ratio. It obtains the optimal results in our simulation model. We consider spectrum channels with 68 sub carriers for both the users. The OFDM symbol has utilized the length of 104.In our simulation results, we have consider multipath channels for the MIMO-OFDM based CRN, which uses the SU receivers, it referred as channel state information (CSI). The probability of the spectrum detection is determined as the average sum of the nonzero entries in b, which is utilized to form the sparse random signal that are exactly detected over the total number of non-zero entries. Later on, the utilized entries represents the subcarriers which have been engaged by the PUs, the probability of the spectrum usage is more or less equal to the probability of the detection. The relative difference between the original signal and the modulated signal is very lesser, which is provided in the table 1.

Table 1: STIMULATION RESULTS

Performance Metrics	Sensing Time T_s (ms)	Normalized Throughput $R(x)$	Probability of false alarm P_f
Non- optimal system with defined T_s	33.64	0.7685	6%
Optimal system with proposed method of adaptive T_s	16.12	0.9345	1.7%

When the spectrum usage is identified by the CR- UWB, then it will employ the compressive spectrum algorithm with significant transmission time to obtain the higher throughput of the SU. Moreover, for the PU activities in the spectrum, it is kept up to 1000/s (i.e., one thousand times per second).The simulation result equates the proposed method have obtained optimal sensing time than normal spectrum sensing, it is demonstrated in the figure.6. It proves that proposed method in the spectrum sensing algorithm has significantly improves the spectrum efficiency, particularly in low SNR regime of the PU.

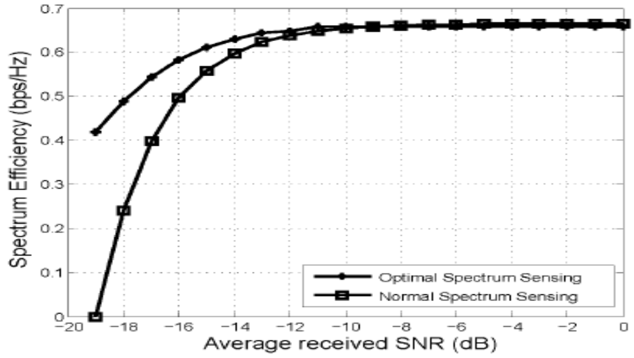

Fig .6 Simulation results

V. CONCLUSION

Spectrum sensing is an essential element for connected the MIMO-OFDM technology inCR, for discovering the primary users signal availability and spectrum usage. In this paper, we have designed the novel hybrid access optimization scheme with energy detector model in order to detect the spectrum usage for providing the protection to primary users. The proposed method can handle optimization problems and provide the access to all the channels with lesser complexity. The proposed method enhances the capacity of the secondary users by minimizing the sensing time and noise ratio through sparsity signal model with orthogonal transformof Fractional Fourier transformation (FRFT). Then modulated signals are performed in DSP (Digital signal Processing). Thus, the proposed system proves to be significant in terms of higher accuracy in detecting the false probability, optimal sensing time, lower transmission power and the achievable throughput than efficient compressive sensing method. In future work, we will investigate on the fading channels and improve the channel strength.

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