Joint Optimization Using Hybrid Spectrum Sensing In Cognitive Radio Networks

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Abstract: ***With the growth of users in wireless and data communication there is a scarcity of additional bandwidth to meet the demand. The efficient utilization of the spectrum bandwidth we go for a technology which is cognitive radio technique. Spectrum sensing is the ability to measure, sense and aware of the parameters related to the radio channel characteristics. In this work uses hybrid spectrum sensing which is the combination of maximum energy detection (MED) and cyclostationary detector. Researchers are focusing on cooperative spectrum sensing to improve reliability but still there is space for improvement in local spectrum sensing. In cooperative spectrum sensing, it will be hard to cooperate with local network nodes in a short time as cognitive radio has to operate in heterogeneous wireless networks. Spectrum sensing and transmission are the two phases of cognitive radio networks. This paper proposes an adaptive spectrum sensing in which cognitive radio can adopt one-order cyclostationary or energy detector for spectrum sensing on the basis of estimated SNR, which is calculated in advance for available channels in first phase. And successive interference canceller detector in transmission phase. Simulation result indicates that ofdm system has better accuracy and performance than cdma system.***

Keywords: Cognitive radio, spectrum utilization, cooperative sensing, CDMA, hybrid spectrum sensing.

1. Introduction

A cognitive radio is an intelligent radio that can be dynamically programmed and configured. Its transceiver is designed to use the best wireless channels. Such a radio automatically detects available channels in wireless spectrum. Then accordingly changes its transmission or reception parameters to allow more concurrent wireless communications. This process is a form of dynamic spectrum management. Two types of users are considered in CRNs, primary user and secondary user. Primary user has permission to access channel at any time. Secondary users are unlicensed users, they can only access channel when channel is idle. Underlay, Overlay and Interweave are the three paradigms of CR. In the interweave paradigm which is based on opportunistic spectrum access, the SUs are able to occupy the portions of the spectrum left temporarily free by the Pus[1],[12].

In this paper we focus on the interweave paradigm which is the original motivation for CR. A major challenge in cognitive radio is that the secondary users need to detect the presence of primary users in a licensed spectrum and quit the frequency band as quickly as possible if the corresponding primary radio emerges in order to avoid interference to primary users. This technique is called spectrum sensing [1],[10]. The important concerns of spectrum sensing are about two things: the primary system should not be disturbed by SU communication and white holes should be detected efficiently for required throughput and quality of service [2].

In practice, many factors such as multipath fading and shadowing may significantly affect the detection performance. To address this issue, cooperative spectrum sensing is used [1],[6] . We know that CDMA is the access method using for it. In this paper utilizes hybrid spectrum sensing.

It includes the combination of maximum energy detection and cyclostationary detector in sensing phase and SIC detector in transmission phase. Except its noise sensitivity maximum energy detector is the best solution to detect free bands, because it doesnot need apriori information. Its complementary method is cyclostationary detector.It is very robust but computationally extensive and needs the prior knowledge of cyclic frequencies inorder to take a quick decision. The proposed hybrid architecture which permits to detect quickly with minimum apriori information of free bands by taking the merits of two methods.

2. Literature Survey

A.Goldsmith Surveys the fundamental capacity limits and associated transmission techniques [3],[11]. 3 paradigms unified and considered CR as intelligent WC. It exploits side information. This side information typically comprises knowledge about the activity, channels, codebooks and/or messages of other nodes with which the cognitive node shares the spectrum. Divide and set aside approach introduced in this paper. The steps are dividing spectrum into distinct bands , assigning specific communication users to specific bands, determining license for each band. The main advantage of the licensing approach is that the licensee completely controls its assigned spectrum, and can thus unilaterally manage interference between its users and hence their quality-of-service (QoS).

Ian F. Akyildiz, Brandon F. Lo, Ravikumar Balakrishnan proposed that Spectrum sensing is a key function of cognitive radio to prevent the harmful interference with licensed users[6]. It can identify the available spectrum for improving the spectrum's utilization. White space/spectrum holes, a promising technology to enable the access of the intermittent periods of unoccupied frequency bands. It also deals with the cooperation method, which is analyzed by the fundamental components called the elements of cooperative sensing ,including cooperation models, sensing techniques, hypothesis testing, data fusion, control channel and reporting, user selection, and knowledge base.

K. Illanko introduced a concept called green cognitive radio [5]. Fast-growing wireless applications consume more and more energy and as a result green radio.

H. Yu investigated the joint spectrum sensing and resource allocation problem to maximize throughput capacity of an OFDM-based cognitive radio link with a cognitive relay. Probability of miss-detection and false alarm are also considered in this paper.

R. Sindhubargavi et.al discussed about hybrid spectrum sensing. Spectrum sensing has different sensing techniques for detecting the signal. MED and cyclostationary detection are discussed .

3. Framework

This project implementing on OFDM system[7] . Hybrid spectrum sensing is working on OFDM system . OFDM is a multicarrier modulation technique that can overcome many problems that arise with high bit rate communications, the biggest of which is time dispersion. OFDM will play an important role in realizing CR concept as well by providing a proven, scalable, and adaptive technology for air interface. Fig 1 gives the block diagram of OFDM system on cognitive radio networks.

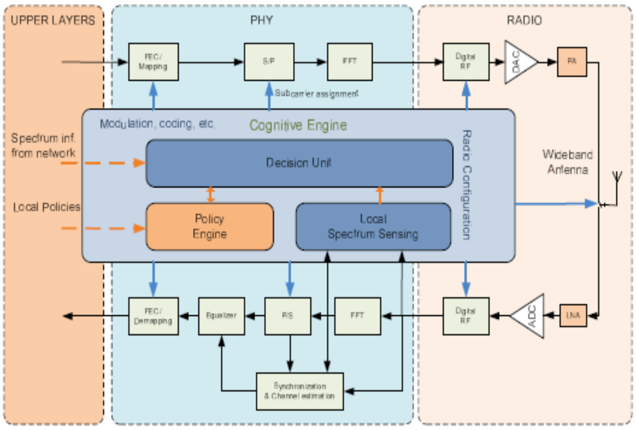


Figure 1: ofdm System on Cognitive Radio Networks

Secondary user transmitted data through ofdm. After that at the receiver of ofdm hybrid spectrum sensing is present.that is in parallel to serial block ofdm receiver. The working block diagram of HSS is given in fig 2. The transmitter detection model is given in equation 1.

$$r(t) = \begin{cases} n(t) & \text{in case of } H_0 \\ hs(t) + n(t) & \text{in case of } H_1 \end{cases} \quad \textbf{(1)}$$

where r(t) is the signal received by CR, s(t) is the transmitted signal of the primary user, n(t) is additive white Gaussian noise (AWGN) and h is the amplitude gain of the channel. H_0 indicates only noise and H_1 indicates the presence of PU. We assume that N is the number of channels to be sensed. The SU estimates the SNR of the channel in advance. Basis of that SNR the SU will select one of the spectrum sensing techniques between the energy detection and the one-order cyclostationary detection having thresholds λ_1 and λ_2 respectively. The energy detector[2] works very poor for low SNRs. Therefore one order cyclostationary detector [2] is used to sense the channel for low SNRs. Likewise for high SNRs energy detector actives. By using this type of adaptive spectrum sensing we can lower the power consumption.

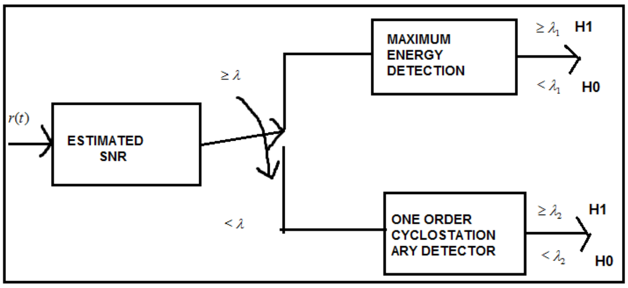


Figure 2: working diagram of HSS

3.1 Maximum Energy Detection

The main concept behind energy detection is the estimation of the maximum power of the recevied signal r(t). To examine the power of the received signal, the output of the band pass filter of band width W is squared and integrated over an interval T. Atlast the integrated value is compared with a threshold λ_1 to decide whether the PU is present or not[2].The probability of detection $P_d^{\,E}$ and probability of false alarm $P_f^{\,E}$ of energy detector over AWGN channel are approximated in [25] as

$$P_d^{\,E} = Q_m(\sqrt{2_\gamma}, \sqrt{\lambda_1}) \quad (2)$$

$$P_f^{\,E} = \frac{\Gamma(M_{E,} \frac{\lambda_1}{2})}{\Gamma(M_E)} \quad (3)$$

Where $\Gamma(.)$ and are complete and incomplete gamma functions, respectively. $Q_m(.,.)$ is the generalized Marcum Q-function, γ is instantaneous SNR, M_E is the time bandwidth product and λ_1 is decision threshold of energy detector.

3.2 One Order Cyclostationary Detection

All processes are not periodic function of time but their statistical features indicate periodicities and such processes are called cyclostationary process. In terms of CRNs the PU (primary user) signals which have these periodicities can be easily detected by taking their correlation which tends to enhance their similarity. When we take the fourier transform of the correlated signal results in peak at frequencies which are specific to a signal and searching for these peaks helps in determining the presence of the PU. The peak value is searched in the time domain and compared with the predetermined threshold λ_2. If periodicity is found (peak value $\geq \lambda_2$), it means that the band is used by PU and vice versa. Noise is random in nature and as such there are no such periodicities on taking the correlation. This is the main merit of cyclostationary detection. That is it can differentiate between different types of signals [2],[4].

The probability of detection P_d^C and probability of false alarm P_f^C of one-order cyclo-stationary detection over AWGN channel are approximated as

$$P_d^C = 1-(1-e^{-\frac{\lambda_2^2}{2\delta_A^2}})^L \quad (4)$$

$$P_f^C = 1-[1-Q_1(\frac{\sqrt{2\gamma}}{\delta}, \frac{\lambda_2}{\delta_A})]^L \quad (5)$$

where δ^2 is the variance, $\delta_A^2 = \delta^2/(2M_C+1)$ in which M_C is the number of samples for detection, L is the number of diversity branches, γ is instantaneous SNR, $Q_1(.,.)$ is the generalized Marcum Q-function and λ_2 is predetermined threshold.

3.3 Problem Analysis

In this section, we will analyze the sensing performance of our proposed scheme. The overall probability of false alarm and probability of detection of two-stage spectrum sensing scheme [2] are given in (6) and (7)

$$P_f = P_r P_f^E + (1-P_r)P_f^C = P_r(P_f^E - P_f^C) + P_f^C \quad (6)$$

$$P_d = P_r P_d^E + (1-P_r)P_d^C = P_r(P_d^E - P_d^C)P_d^C \quad (7)$$

where P_r is the probability that a channel would be reported to energy detector as the second stage and therefore, the probability that a channel would be reported to one-order cyclostationary detector will be $1-P_r$. P_r is dependent on SNR of the channels to be sensed and overall P_f and P_d directly depend on *Pr*. For the cooperative spectrum sensing[ ] P_D and P_F can be found to be:

$$P_D = 1-\prod_{i=1}^{N}((1-p_{d_i})(1-p_{e_i}) + p_{d_i}p_{e_i}) \quad (8)$$

$$P_F = 1-\prod_{i=1}^{N}((1-p_{f_i})(1-p_{e_i}) + p_{f_i}p_{e_i}) \quad (9)$$

3.4 SIC In Transmission Phase

In the cognitive radio (CR) system, power control is a key enabling technique to ensure quality-of-service (QoS) provisioning for primary users (PUs) and secondary users (SUs). How to efficiently allocate power to SUs is not a trivial work, especially, in CDMA based CR systems with successive interference cancellation (SIC) [8], After the hybrid spectrum sensing, if PU's channel is estimated to be idle, SUs access the channel. To improve the system performance and to reduce the multiple access interference we use successive interference canceller (SIC) detector with predefined decoding order at secondary base station. Here the secondary base station under consideration decodes users signals in sequence. Once the kth SU is decoded, the reconstructed signal for this user is removed from the composite signal [1].

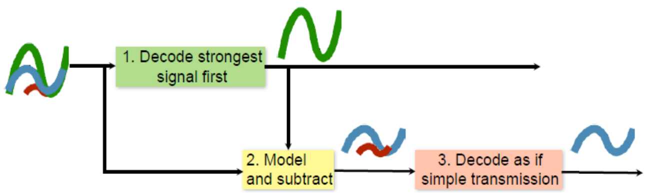


Figure 3: Working of SIC

4. Simulation Results

In this section, we compare our proposed approach of spectrum sensing with the energy detection and the one-order cyclostationary detection. Here N=1000 samples, P_f =0.1 to 0.7. Fig 4.1 gives the idea of performance comparison between HSS and cooperative spectrum sensing. Fig 4.2 (a) & (b) are about effect of sensing parameters on energy consumption. in lower false alarms more channel access chances exist which increase the power consumption while at the same time the required powers to reach the QoS requirements are lower. Also it can be inferred that under fading sensing channel, the optimal false alarm and energy consumption is higher than in AWGN case.

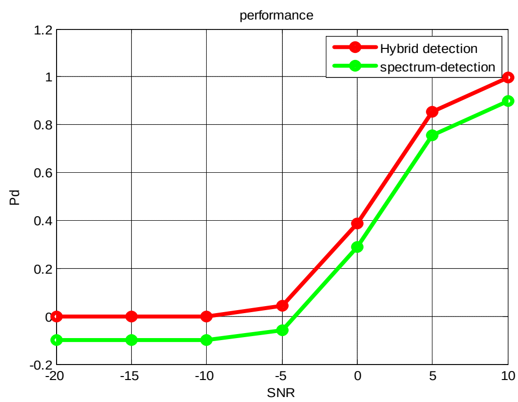
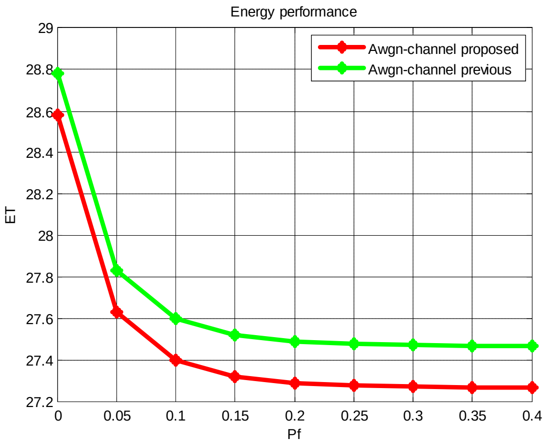
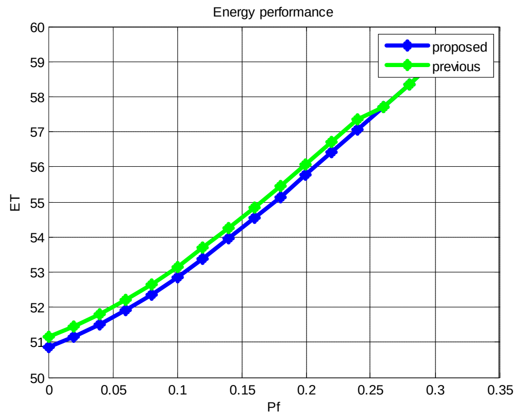


Figure 4.1: Performance comparison between HSS & cooperative spectrum sensing



(a) $\alpha_k = 0.01 bit/\sec/HZ$



(b) $\alpha_k = 0.5 bit/\sec/HZ$

Figure 4.2: Effect of sensing parameter on energy consumption

Fig 4.3 illustrates the minimum energy consumption per time slot. There are N=3 SUs and two data rates of 0.01bit/sec/HZ and 0.5 bit/sec/HZ is considered. We can see that when the probability of false alarm increases the amount of minimum energy consumption also increases.

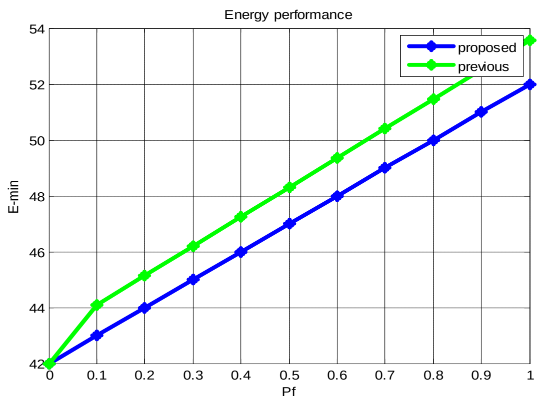


Figure 4.3: Minimum energy performance

Fig 4.4 illustrates the BER v/s SNR of the OFDM system. We know that cooperative spectrum sensing is implemented in CDMA system, where large number of users are present. Accordingly CDMA system has large noise. But this project efficiently decreases the interference and improves the accuracy.

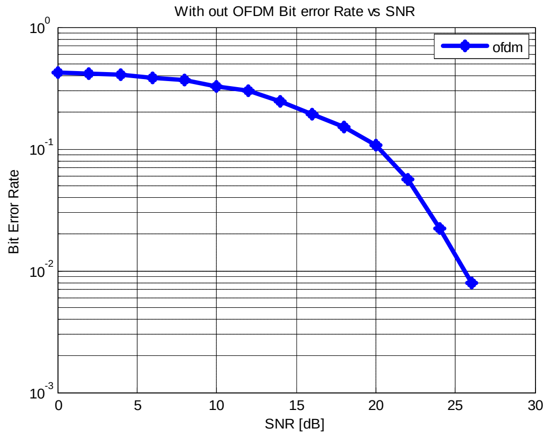


Figure 4.4: Performance of OFDM system

5. Conclusion

Joint optimization using hybrid spectrum sensing is implemented in OFDM system. We know that Hybrid spectrum sensing can increase the spectral efficiency. Two well-known spectrum sensing techniques such as Maximum energy detection (MED) and cyclostationary based detection are used in this project. The two-stage spectrum sensing method urge to achieve better spectrum sensing for cognitive radio at a cost of high computational complexity in low SNR environment. SIC in transmission phase reduces overall interference. Project also compares the performance of hybrid spectrum sensing with cooperative spectrum sensing. From the simulation results we can easily understand the advantage of spectrum sensing.

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