Game Theory Based Spectrum Sensing Technique Using Cognitive Radio Networks

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Abstract: In Cognitive Radio Networks, though energy detection technique is simple with short sensing time, its performance is poor under low Signal to Noise Ratio (SNR) conditions. Hence in this paper, we propose to design an optimized adaptive spectrum sensing technique Using Game Theory Model for Cognitive Radio Networks. Initially, the secondary users decide the sensing technique to be applied based on the utility function in terms of the energy and throughput. By simulation results, we show that the proposed technique maximizes the energy efficiency and detection accuracy.

I. Introduction

1.1 Cognitive Radio Networks (CRN)

Cognitive Radio (CR) is a key technology that can help mitigate scarcity of spectrum. Cognitive radios are designed in order to provide highly reliable communication for all users of the network, wherever and whenever needed. CRN also facilitates effective utilization of the radio spectrum. Cognitive radio can change its transmitter parameters based on interaction with environment in which it operates [1] [6].

The most essential task of CR is to detect licensed user/Primary User (PU); if PU is absent, and then spectrum is available for cognitive radio user/Secondary User (SU) and is called spectrum hole/white space. The process of detection of PU is achieved by sensing radio environment and is called spectrum sensing. The prime concerns of spectrum sensing are about two things: first, the primary system should not be disturbed by SU communication and secondly, spectrum holes should be detected efficiently for required throughput and quality of service (QoS) [6].

Cognitive radio consists of four main functional blocks:

1.2 Spectrum sensing in CRN

Spectrum sensing is defined as the task of finding spectrum holes by sensing the radio spectrum in the local neighborhood of the cognitive radio receiver in an unorganized manner. The term “spectrum holes” stands for those sub-bands of the radio spectrum that are underutilized at a particular instant of time and specific geographic location. To be particular, the task of spectrum sensing involves the following subtasks:

1. Detection Of Spectrum Holes;
2. Spectral Resolution Of Each Spectrum Hole;
3. Estimation Of The Spatial Directions Of Incoming Interferes;
4. Signal Classification; [2]

1.3 Classification of Spectrum sensing

The spectrum sensing can be classified as follows

1. Interference Based Sensing
2. Cooperative Sensing
3. Non-Cooperative Sensing
   • Energy Detection
   • Matched Filter Detection
   • CyclostationaryFeature Detection

1.4 Problem Identification:

Waleed Ejaz1 et al [12] examines the energy-throughput trade-off for cooperative spectrum sensing and formulates an optimization problem for secondary users based on spectrum sensing efficiency. They have used the energy detector model for spectrum sensing and applied k-out-of-N rule for decision fusion rule. Though energy detection is a simple technique that has short sensing time, its performance is poor under low Signal to Noise Ratio (SNR) conditions [6]. Also, considering the minimization of energy consumption as
an objective for optimizing the parameters of the fusion rule will degrade the throughput [13]. In order to solve these issues, we propose to design an adaptive spectrum sensing technique for CR networks using game theory.

II. Literature Review

Vamsi Krishna Tumuluru et al [3] have proposed to develop an opportunistic spectrum scheduling scheme for multi-channel cognitive radio networks. The scheduling is performed at the beginning of the frame which consists of multiple slots. The scheduling algorithm estimates the expected number of packets which can be transmitted over the frame by each secondary user for each licensed channel. They present a Markov chain formulation to calculate the expected number of packets which can be transmitted over the frame for a secondary user corresponding to each licensed channel. Based on these expected packet transmissions, a central scheduler allocates the licensed channels to the secondary users. The objective of the scheduling algorithm is to allocate the licensed channels to maximize the aggregate throughput of the secondary users. However there occurs scheduling overheads.

Li Zhang et al [4] have proposed a general scheduling framework for solving the Maximum Throughput Channel Scheduling problem (MTCS). Based on the proposed framework, they present two polynomial time optimal algorithms to solve the MTCS in the homogeneous and the heterogeneous traffic load cases, respectively. On average, the proposed algorithms outperform a greedy algorithm by 21.6%. Index Terms—Cognitive radio networks, white-space, mobility, spectrum hand-off, scheduling, channel assignment.

Wael Guibene et al [5] have presented a new standpoint for spectrum sensing emerging in detection theory, deriving from differential algebra, non-commutative ring theory, and operational calculus. The proposed algebraic based algorithm for spectrum sensing by change point detections in order to emphasizes “spike-like” parts of the given noisy amplitude spectrum. The proposed approach is very efficient to detect the occupied sub-bands in the primary user transmissions.

Feng Lin et al [8] have proposed a function of covariance matrix based spectrum sensing approach for cognitive radio systems. Collaborative sensing scenario is introduced for the proposed algorithm, in which each sensor only needs limited sample data for calculation and sends mediate result to fusion center. A performance comparison among different rational functions is provided, which shows different functions in this algorithm may have similar or distinct performance. So it is important to choose an appropriate function. The proposed algorithm has a reliable performance in very low signal-to-noise ratio (SNR) condition, and outperforms the Estimator-Correlator (EC) approach.

Compressive Wideband Power Spectrum Estimation technique and dynamic compressive spectrum sensing techniques are proposed in [9] and [11], respectively and utility based co-operative spectrum sensing technique has been proposed in [10].

III. Proposed Method

3.1 Overview

In this paper, we propose to design an optimized adaptive spectrum sensing technique Using Game Theory Model for Cognitive Radio Networks. In the game theory model, the secondary users (SU) can decide the sensing technique to be applied based on the utility function. The SU estimates the SNR of each channel in advance and forms the utility function in terms of the energy and throughput. Then the sensing technique is adaptively determined based on the SNR value. (ie) At low SNR values, the one-order cyclostationary detection technique is applied whereas at high SNR values, the energy detector is applied. The decision thresholds $\lambda_1$ and $\lambda_2$ of energy detector and one-order cyclostationary detector, respectively, are adjusted such that the utility is maximum.

3.2 Basics of Game Theory

The game $Z$ is defined as $Z = (N, S, \{UF_i\})$.

where $N$ = finite set of players

$S$ = action space formed as Cartesian product. i.e. $S = S_1 \times S_2 \times S_3 \times S_4 \times ... \times S_n$

$UF_i$ = utility functions. $\{UF_1, UF_2, ..., UF_n\}$

The main applications of game theory are as follows

1) Decision making in many economic problems especially during bidding.

2) Power control to set the power level of nodes. This is performed to maximize their signal interference to noise ratio (SINR), their selection of path by source node to minimize delay, and their cooperation among the nodes to identify the service and forwarding of the packets to their destination.
3.3 Detection Technique
We consider the following two detection technique
- Energy Detection
- One-order Cyclo-stationary detection

3.3.1 Energy Detection: The energy detection represents the estimation of power of the received signal. If the estimated received signal is greater than the threshold, then the nodes use the energy detection technique.

3.3.2 One-Order Cyclo-stationary: In general, the primary modulated wave-forms are coupled with patterns characterized as cyclo-stationary features like sine wave carriers, pulse trains, repeating spreading, hoping sequences or cyclic prefixes inducing periodicity. The cognitive radio can detect a random signal with a specific modulation type in the presence of random stochastic noise by exploiting the periodic statistics like mean and auto-correlation of the primary waveform. The cyclo-stationary detection is based on auto-correlation function. However, in order to improve the channel sensing in time domain, we consider one-order cyclo-stationary detection. This in turn reduces the complexity and power consumption.

We detect the optimal spectrum sensing technique by applying game theory which is described in following section.

3.4 Game Theory Based Spectrum Sensing Technique Decision
In the game theory model, the secondary user (SU) decides which sensing technique can be applied based on the utility function. The SU estimates the SNR of each channel in advance and forms the utility function in terms of the energy and throughput.

Let ST be the sensing technique.

\[ ST: \{ x, y, \lambda_1, \lambda_2 \} \]

ST represents the rule that selects four-tuple \( \{ x, y, \lambda_1, \lambda_2 \} \) to transmit at time slot \( t \).

Where \( \{ \lambda_1, \lambda_2 \} \) = sensing technique thresholds (energy detection and one-order cyclo-stationary detection respectively).

IV. Simulation Results
4.1 Simulation Parameters
We use Matlab version 7.12(R2011a) [14] to simulate our proposed Optimized Adaptive Spectrum Sensing Technique Using Game Theory Model (OASST) protocol. In our simulation, the number of nodes is taken as 50. The area size is 100 meter x 100 meter square region.

Our simulation settings and parameters are summarized in table 1

<table>
<thead>
<tr>
<th>No. of Nodes</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>100 X 100</td>
</tr>
<tr>
<td>SNR</td>
<td>-10 dB</td>
</tr>
</tbody>
</table>

In this scenario, it is assumed that the average SNR is -10dB. The result shows that the existing adaptive scheme performs better than the energy detector but equally to the one-order cyclo-stationary detector.

![Simulation Topology](image)
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V. Conclusion

In this paper, we have proposed to design an optimized adaptive spectrum sensing technique Using Game Theory Model for Cognitive Radio Networks. Initially, the secondary users decide the sensing technique to be applied based on the utility function in terms of the energy and throughput. By simulation results, we have shown that the proposed technique maximizes the energy efficiency and detection accuracy.

References