Performance Analysis of a Cognitive Radio Using MRC and SC Techniques

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Abstract: ***The wide growth of wireless communication leads to the scarcity of frequency spectra and available radio spectrum is a limited natural resource, being congested day by day. A possible solution is the use of Cognitive Radio (CR) technology which is a radio or system; it has the ability to the use of available spectrum on the frequency band effectively. In this paper we propose a framework for the performance analysis cooperative spectrum sensing (CSS) in cognitive radio network using maximal ratio combining and selection combining techniques. Also we propose to use a powerful acceleration algorithm for a series of iteration with finite number of time series to investigate the convergence rate. We investigates the detection accuracy varies with number of diversity branches, the fading severity and the power constraints. The result obtained reveals the relaying link statistics and performance analysis of the network using the diversity techniques.***

Keywords: Cooperative spectrum sensing, cognitive radio(CR),maximal ratio combining(MRC), selection combining(SC),convergence acceleration.

1. Introduction

In cognitive radio networking signal detection has a key role in spectrum sensing. Many of the pre-allocated frequency bands are ironically under-utilized; the resources they are simply wasted. It has been found that t he allocated spectrum is underutilized for static allocation of the spectrum. The conventional approach to the spectrum management is not flexible. To operate, every wireless operator is assigned a sole license in a certain frequency band. It is difficult to find the vacant bands to deploy new services and enhance existing ones. To overcome this cognitive radio technology is used.

Signal detection aims to detect whether there is an unused portion if the licensed spectrum to provide opportunities for secondary users to access the available bands in the absence of primary users. Primary users, have the rights of priority in using certain stable frequency bands for communications, secondary users are allowed to use the frequency spectra momentarily only if they do not interfere with the primary users. So the ability of sensing an idle spectrum and the ability to temporarily utilize a spectrum without interfering with primary users are two essential components required for the success of cognitive radios.

So we have to analyze the performance of cooperative spectrum sensing in cognitive radio network using two diversity techniques called maximal ratio combining techniques and selection combining techniques. The approach employs AF relaying protocol due to its better performance compared with DF relaying protocol. Accordingly, each CR carries out local sensing within a specified period of time, the act as a relay, and forwards the local sensing to the fusion center. Based on the combined inputs the fusion center decides whether the primary network is active or not. In the DF protocol, CR users perform local detections and only forward decisions to the fusion center. AF protocol provides higher diversity gain and better detection accuracy.

2. Motivation and Related Works

Cooperative spectrum sensing [1]used to increase the detection accuracy without imposing higher sensitivity requirements on the individual CR network. A comprehensive framework for the performance analysis of multi-hop multi-branch wireless communication over Log-Normal fading channels. The framework allows to estimate the performance OF Amplify and Forward (AF) relay method for both Channel State Information (CSI) assisted relays and fixed gain relays .in particular the contribution of this paper is twofold: i) first of all, by relaying the Gaussian Quadrature Rule representation of the MGF for a Log-Normal Distribution; ii) simplify the computational burden of the former frame work for some system setups, we propose various approximations, which are based on the Improved Schwartz- Yeh method.

CSS approaches are investigates under the typical assumption of AWGN channel [2]. A cognitive radio technology has been proposed to improve spectrum efficiency by having the cognitive radios act as secondary users to opportunistically access under-utilized frequency bands. Spectrum sensing, as a key enabling functionality in cognitive radio networks, needs to reliably detect signals from licensed primary radios to avoid harmful interference. However, due to the effects of channel fading/shadowing, individual cognitive radios may not be able to reliably detect the existence of a primary radio. In this paper, we propose an optimal linear cooperation framework for spectrum sensing in order to accurately detect the weak primary signal. Within this framework, spectrum sensing is based on the linear combination of local statistics from individual cognitive radios.

In the existing system, it considers cooperative spectrum sensing problem for a cognitive radio (CR) mesh network, where secondary users (SUs) are allowed to share the spectrum band which is originally allocated to a primary users' (PUs) network. We propose two new cooperative spectrum sensing strategies, called amplify-and-relay (AR) [3] and detect-and-relay (DR) [3], aiming at improving the detection performance with the help of other eligible SUs so as to agilely vacate the channel to the primary network when the neighboring PUs switch to active state. AR and DR strategies are periodically executed during the spectrum sensing phase which is arranged at the beginning of each MAC frame. Based on AR and DR strategies, we derive the closed-form expressions of false alarm probability and detection probability for both single-relay and multi relay models, with or without channel state information (CSI). Simulation results show that our proposed strategies achieve better performance than a non-cooperative (or non-relay) spectrum sensing method and an existing cooperative detection method. As expected, we observe that the detection performance improves as the number of eligible relay SUs increases, and furthermore, it is better for the known-CSI case than that of the unknown CSI case.

Previously described systems have many disadvantages and they are the spectrum allocation is low, sensitivity to noise, decision fusion policy can outperforms soft fusion policy if a large number of users are involved in the cooperative sensing.

3. Implementation

Cognitive radio is a form of wireless communication where a transceiver can intelligently detect the channels for communication which are in use and which are not in use, and move into unused channels while avoiding occupied ones. In order to increase the performance we derive an expression for the average probability and the average false alarm probability using two diversity techniques called maximal ratio combining and selection combining techniques.

A powerful acceleration algorithm called Wynn's-ε algorithm to determine the convergence acceleration for infinite series. Also we assume that all channels experience independent not identically distributed Nakagami –m fading channel.

3.1 System Model

We are considering a centralized CR network with L active secondary users. The secondary user operates in a fixed time division multiple access schemes. Data transmitted to the fusion centre during two phases: sensing phase and transmission phase. During the sensing phase , it consist of two slots. In the first slot all CR listens to the primary users signal and during the second slot it amplifies the signal and transmit it to the fusion center.

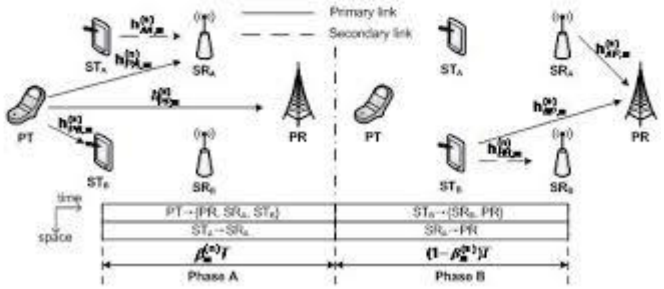

Figure 1(a): System model.

The power constraints of the CR network are defined below. It has maximum power constraints Pi. It measures the average received signal power and allowing pilot symbols to be transmitted at regular interval. Each CR has channel state information. Let Xp denotes the primary signal, Ai denotes the amplification gain which is proportional to maximum power constraints.

$$Ai = \frac{Pi}{Ei+No} \quad (1)$$

3.2 Selection Combining Scheme

Diversity combining technique is the technique applied to combining multiple received signal of a diversity reception device into a single improved signal. In the performance analysis of cooperative diversity techniques, maximum set of information is considered. In order to select the relaying link that has the highest gain among all the diversity branches we are considering the selection combining schemes. Any additional gain diminishes rapidly with the increasing number of channels. This is a more efficient technique than switched combining In this scheme, two strategies are considered: i) the combiner selects the relaying branch with highest SNR (γr). ii) the relay with highest min($\gamma s, \gamma r$) is selected. We are considering two hypotheses Ho and H1.
Ho: absence of primary users.
H1: presence of primary users.
Instead of SNR, channel gain is used to determine the two hypotheses. If Y denotes the signal power at the output combiner, then the mean value of Y for a given g can be expressed as

$$E\{Y/g\} = \begin{cases} \sigma yo = No(1 + Ascg)Ho \\ \sigma yo = No(1 + (1 + \gamma sc)Ascg)H1 \end{cases} \quad (2)$$

Sometimes more than one combining technique is used for example, lucky imaging uses selection combining to choose the best 10% images, followed by equal-gain combining of the selected images. Other signal combination techniques have been designed for noise reduction and have found applications in single molecule biophysics and chemo metrics among others.

3.3 Maximal Ratio Combining schemes

In telecommunications, maximal-ratio combining (MRC) is a method of diversity combining in which: the signals from each channel are added together, the gain of each channel is made proportional to the rms signal level and inversely proportional to the mean square noise level in that channel and different proportionality constants are used for each channel. It is also known as ratio-squared combining and prediction combining. Maximal ratio combining is the optimum combiner for independent AWGN channels. MRC can restore a signal to its original shape

In many performances analysis determination of sum of the squared envelopes of the faded signals over several fading signals over diversity paths uses MRC schemes.MRC receiver weighs its input signal with their channel statistics and is known to be of high performance.

Average detection probability of MRC schemes can be expressed as

$$Pd = [k \prod_{j=1}^{L} \left(-\frac{\beta j}{(1+\gamma s)Aj}\right) m] \sum_{j=1}^{l} \sum_{v=1}^{m} (-1)bjv \times \sum_{q=0}^{mj-1} \frac{1}{q!} \left(\frac{mj\mu}{No}\right) \tag{3}$$

Average false alarm probability can be expressed as

$$Pf = \frac{\beta}{Ai} \sum_{q=0}^{m-1} \frac{1}{q!} \left(\frac{m\mu}{No}\right) \sum_{n=0}^{\infty} (-1)bn \times \cup (Lm: Lm + 1 - q - n:) \frac{\beta}{(1+\gamma s)A} \tag{4}$$

3.4 Convergence Acceleration

Convergence acceleration is one of a collection of sequence transformations for improving the rate of convergence of a series. Techniques for series acceleration are often applied in numerical analysis, where they are used to improve the speed of numerical integration. Series acceleration techniques may also be used, for example, to obtain a variety of identities on special functions. Detection probability and false alarm probability can evaluated accurately using this method. Series acceleration improves the rate of convergence of infinite series through sequence transformation algorithms.

4. Simulation Results

The proposed system can be analyzed through simulation. In fig 2, we compare the analytical results obtained for detection probability with the threshold value λ. Compared with MRC scheme the approximated curve of SC scheme shows wider mismatch and the approximation errors in the case of the MRC scheme are less than those of the SC scheme.

In fig 3, we describe the receiver performance characteristics of the system. The performance of the proposed AF approach is compared with the DF approach for different channel condition. The figure shows AF approach outperforms the DF approach to the selected values of fading parameter m.

In fig 4, we plot average detection probability versus relay power constraint P to demonstrate the importance of the diversity reception. When L=1 results no diversity scenario. In this case the curve of MRC coincides with that of the SC scheme. From the graph, it is clear that higher diversity gain is achieved when the number of cooperative users increases. When L=4 users the MRC receiver achieves 8dB gain less than the no diversity cases, whereas the SC -3 dB gain. From all these evaluation , we conclude that MRC scheme outperforms the SC schemes .

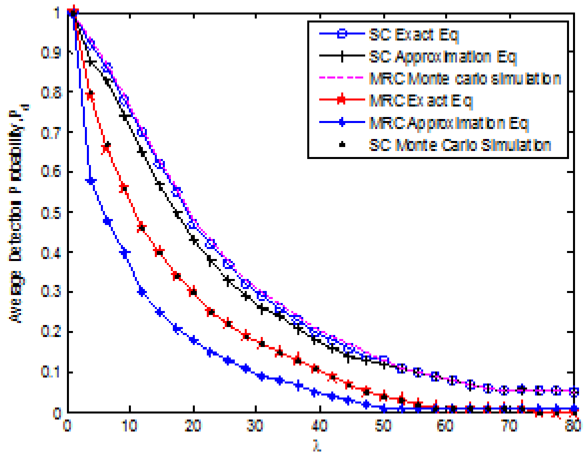

Figure 2: Comparison of MRC and SC for different *Pd*. P = 5dB L = 3, m = 3.

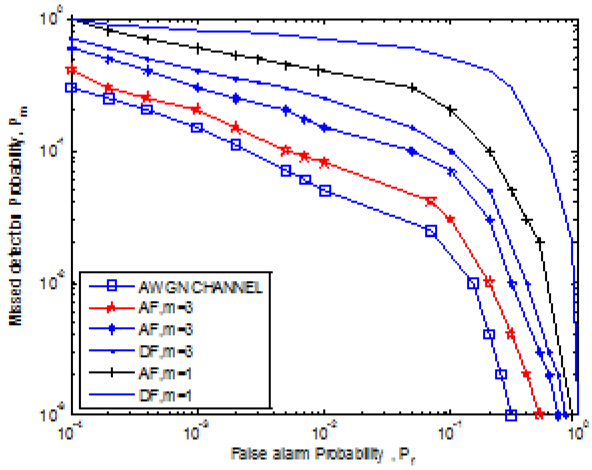

Figure 3: Receiver performance characteristics curves at different relaying conditions.

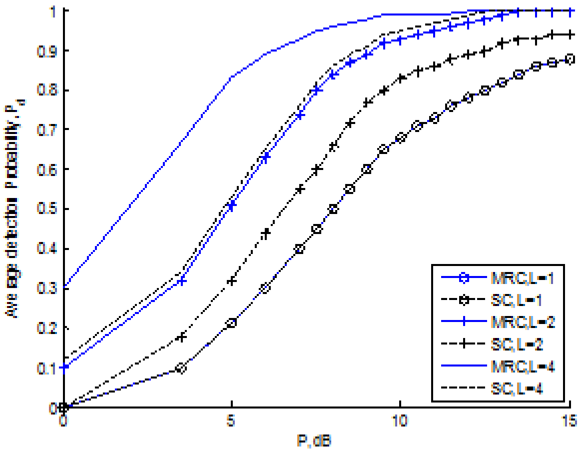

Figure 4: Average detection probability versus relay power

5. Conclusion

In this paper, we analyzed the performance of cooperative spectrum sensing for CR network application over Nakagami-m fading channel. Also investigate the detection accuracy with various diversity branches, the fading severity and power constraints. The main advantage of this paper is that there is no need to increase the relaying power if a probability detection is achieved. In the MRC scheme it achieves 8dB gain when four cooperative users are engaged. Also MRC scheme outperforms the SC schemes.

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