Performance evaluation of Relay based Cooperative Spectrum Sensing in Cognitive Radio Network

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Abstract

Cognitive radio is a promising technology that enables an unlicensed user (also known as a cognitive user) to identify the white space of a licensed spectrum band (called a spectrum hole) and utilize the detected spectrum hole for its data transmissions. To design a reliable and efficient cognitive radio system, there are two fundamental issues: to devise an accurate spectrum sensing algorithm to detect spectrum holes as accurately as possible; and to design a secondary user transmission mechanism for the cognitive user to utilize the detected spectrum holes as efficiently as possible. This article investigates and shows that cooperative relay technology can significantly benefit the above mentioned two issues, spectrum sensing and secondary transmissions. We summarize existing research about the application of cooperative relays for spectrum sensing (referred to as the cooperative sensing) and address the related potential challenges In this paper we studied and compare two cooperation diversity schemes in energy detector for cognitive radio networks. Energy detector is equipped with the MRC and EGC where spectrum sensing performance is evaluated .Both the schemes are compared in single and multiple cognitive relay scenarios. The cognitive relays used amplify and forward decoded and forward relaying scheme.

Keywords: - **Amplify and forward, decode and forward, detection cooperative spectrum sensing, cognitive radio, energy detection.**

1. Introduction

Cognitive radio is emerging as a promising technology for future radio networks [1, 2], which enables an unlicensed cognitive user to recognize (by spectrum sensing) and access a spectrum hole that is a radio frequency band licensed to a primary user but not used by that user. Cognitive radio typically exploits the spectrum sensing to detect spectrum holes for secondary transmissions so that the primary and secondary users can share spectrum resources without harmful interference. In general, ideal spectrum sensing (without miss detection and false alarm) cannot be realized in practice and thus mutual interference between the primary and cognitive users exists, which severely impairs and limits the secondary transmission performance under a target primary quality of service (QoS) requirement, especially with a strict primary QoS constraint [3]. In order to achieve a reliable cognitive radio system with high data rates, it requires both a spectrum sensing algorithm and an efficient secondary transmission mechanism so as to detect and utilize the spectrum holes in the most efficient way. To that end, cooperative relay technology is considered as an effective method to improve the performance of both spectrum sensing and secondary transmissions.

Cooperative relay technology has been studied extensively for traditional wireless networks [4]. A reliable cognitive radio system with high data rates is achievable by using cooperative relays for both the spectrum sensing and secondary transmissions. However, the two individual designs of spectrum sensing and secondary transmissions cannot be optimized separately, since they affect each other [5, 6]. For example, when an available spectrum hole is not detected by spectrum sensing during a certain observation window, the spectrum hole utilization would decrease. To alleviate this issue, we may increase the observation time for the spectrum sensing phase, which, however, comes at the cost of degradation in secondary transmission performance since less time is now available for the secondary transmission phase. In [6], we investigate the sensing and transmission trade-off in a multiple-relay cognitive radio network and show that a significant performance improvement is obtained by using cooperative relays in terms of the spectrum hole utilization.

2. System Model

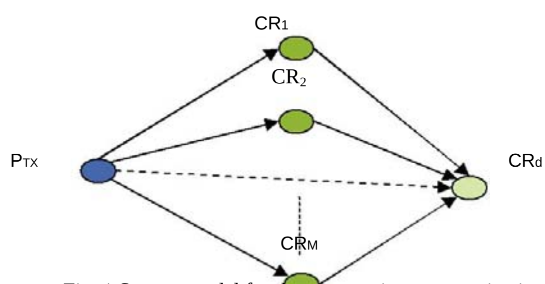

Fig. 1 System model for the cooperative communication

Fig. 1 shows the system model for the cooperative communication. In cooperative spectrum sensing, the relay stations are introduced in the CR network. In this model, CR1, CR2..CRM are within effective transmission radius (rp) of primary transmitter (PTX). Hence, the detection probabilities of CR1, CR2..CRM will be high. But CRd is beyond rp. Hence, it is hard for CRd to take decision about the presence or absence of PU. To improve the performance of spectrum sensing of CRd, we consider that CR1, CR2..CRM sense the activity of the PU individually and send their received data to CRd. The effective transmission radius of each CR is rc. CR1, CR2..CRM and CRd are within each other's communication area. In our model, PTX is the source node; CR1, CR2... CRM are the relay nodes and they work on time division duplex mode; CRd is the destination node. The time frame of each relay CR is divided into two slots. In the first time slot, each relay CR received the signal of PU. In the second time slot, the relay CRs amplify the received signals and send the amplified signals to the destination CR. Signal from relays and signal of direct link is combined by maximal ratio combining (MRC).

3. Preliminary

3.1 Cognitive Radio

As the demand for additional bandwidth continues to increase, spectrum policy makers and communication technologists are seeking solutions for the apparent spectrum scarcity [7], [8]. Meanwhile, measurement studies have shown that the licensed spectrum is relatively unused across many time and frequency slots [9]. To solve the problem of spectrum scarcity and spectrum underutilization, the use of CR technology is being considered because of its ability to rapidly and autonomously adapt operating parameters to changing requirements and conditions. Recently, the FCC has issued a Notice of Proposed Rulemaking regarding CR [10] that requires rethinking of the wireless communication architectures so that emerging radios can share spectrum with PUs without causing harmful interference to them. In the pioneering work [1], Mitola and Maguire stated that Bradio etiquette is the set of RF bands, air interfaces, protocols, and spatial and temporal patterns that moderate the use of radio spectrum. CR extends the software radio with radio-domain model-based reasoning about such etiquettes. In Haykin's paper [11], it was stated that cognitive radio is an intelligent wireless communication system that is aware of its surrounding environment (i.e., its outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming radio frequency (RF) stimuli by making corresponding changes in certain operating parameters (e.g., transmit power, carrier frequency, and modulation strategy) in real time, with two primary objectives in mind:

1) Highly reliable communications whenever and wherever needed
2) Efficient utilization of the radio spectrum.

Another CR description is found in Jondral's paper [12], which states that Ban SDR that additionally senses its environment, tracks changes, and reacts upon its findings. More specifically, the CR technology will enable the users to [13]:

- determine which portions of the spectrum are available and detect the presence of licensed users when a user operates in a licensed band (spectrum Sensing)
- select the best available channel (spectrum management)
- Coordinate access to this channel with other users (spectrum sharing).
- Vacate the channel when a licensed user is detected (spectrum mobility).

3.2 Cooperative Communications

Traditional wireless networks have predominantly used direct point-to-point or point-to-multipoint (e.g., cellular) topologies. In contrast to conventional point-to-point communications, cooperative communications and networking allows different users or nodes in a wireless network to share resources and to create collaboration through distributed transmission/processing, in which each user's information is sent out not only by the user but also by the collaborating users [14]. Cooperative communications and networking is a new communication paradigm that promises significant capacity and multiplexing gain increase in wireless networks. It also realizes a new form of space diversity to combat the detrimental effects of severe fading.

There are mainly two relaying protocols: amplify-and forward (AF), decode-and-forward (DF) In AF, the received signal is amplified and retransmitted to the destination. The advantage of this protocol is its simplicity and low cost implementation. But the noise is also amplified at the relay. In DF, the relay attempts to decode the received signals. If successful, it re-encodes the information and retransmits it

4. Spectrum Sensing Techniques

One of the most important components of CR is the ability to measure, sense, learn, and be aware of the parameters related to the radio channel characteristics, availability of spectrum and power, interference and noise temperature, radio's operating environment, user requirements, and applications [15]. In CR, the PUs are referred to those users who have higher priority or legacy rights on the usage of a part of the spectrum. Spectrum sensing is a key element in CR communications, as it enables the CR to adapt to its environment by detecting spectrum holes. The most effective way to detect the availability of some portions of the spectrum is to detect the PUs that are receiving data within the range of a CR. However, it is difficult for the CR to have a direct measurement of a channel between a primary transmitter and receiver. Therefore, most existing spectrum sensing algorithms focus on the detection of the primary transmitted signal based on the local observations of the CR.

Energy Detection: If prior knowledge of the PU signal is unknown, the energy detection method is optimal for detecting any zero-mean constellation signals [16]. In the energy detection approach, the radio-frequency (RF) energy in the channel or the received signal strength indicator is measured to determine whether the channel is idle or not. First, the input signal is filtered with a band pass filter to select the bandwidth of interest. The output signal is then squared and integrated over the observation interval. Lastly, the output of the integrator is compared to a predetermined threshold to infer the presence or not of the PU signal. When the spectral is analyzed in the digital domain, fast Fourier transform (FFT) based methods are used.

5. Cooperative Sensing Techniques

The critical challenging issue in spectrum sensing is the hidden terminal problem, which occurs when the CR is shadowed or in severe multipath fading. Fig. 2 shows that CR 3 is shadowed by a high building over the sensing channel. In this case, the CR cannot sense the presence of the primary user, and thus it is allowed to access the channel while the PU is still in operation. To address this issue, multiple CRs can be designed to collaborate in spectrum sensing. Recent work has shown that cooperative spectrum sensing can greatly increase the probability of detection in fading channels [17]. For an overview of recent advances in cooperative spectrum sensing, readers are referred to [18]. In general, cooperative spectrum sensing can be performed as described below:

Cooperative Spectrum Sensing:

1) Every CR performs its own local spectrum sensing measurements independently and then makes a binary decision on whether the PU is present or not.
2) All of the CRs forward their decisions to a common receiver.
3) The common receiver fuses the CR decisions and makes a final decision to infer the absence or presence of the PU.

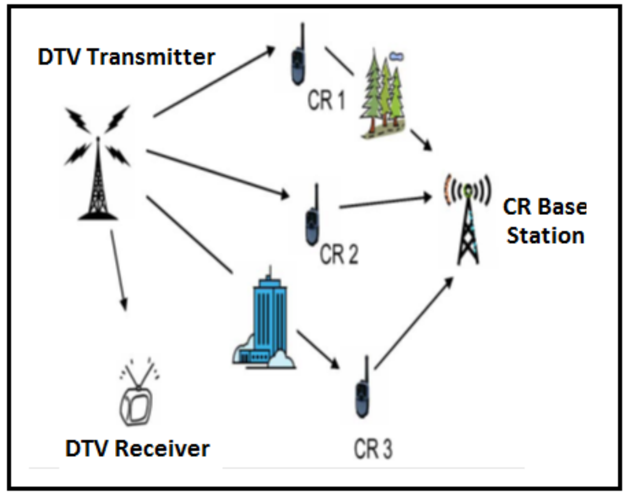

Fig.2 co-operative spectrum sensing in CR radio networks.

6. Diversity Combining Techniques

A) Maximal Ratio Combining

Maximal ratio combining takes better advantage of all the diversity branches in the system. In this configuration for a two-branch diversity system. Both branches are weighted by their respective instantaneous voltage-to-noise ratios. The branches are then co-phased prior to summing in order to insure that all branches are added in phase for maximum diversity gain. The summed signals are then used as the received signal and connected to the demodulator. Maximal ratio combining will always perform better than either selection diversity or equal gain combining because it is an optimum combiner. The information on all channels is used with this technique to get a more reliable received signal. The disadvantage of maximal ratio is that it is complicated and requires accurate estimates of the instantaneous signal level and average noise power to achieve optimum performance with this combining scheme. The advantage is that improvements can be achieved with this configuration even when both branches are completely correlated.

B) Equal Gain Combining

Equal gain combining (EGC) can be viewed as a special case of maximal ratio combining In this scheme the gains of the branches are all set to a predetermined value and are not changed. As with the previous case, both branch signals are multiplied by the same branch gain (G) and the resulting signals are co-phased and summed. The resultant output signal is connected to the demodulator

7. Conclusion

This paper describes the application of cooperative relays for both the spectrum sensing and secondary transmissions to achieve a reliable and efficient cognitive radio system. We present a selective-relay-based cooperative sensing scheme without a dedicated channel to report initial detection results for fusion and show its advantage over traditional cooperative sensing (with a dedicated reporting channel). Based on two relaying strategies, namely, the amplify-and-forward strategy and the detect-amplify-and-forward strategy, We analyzed the way the detection accuracy varies with the number of cooperative users we show the importance of including the relaying channel propagation characteristics to the analysis and design of cognitive radio Networks. We also observed that the DAF strategy outperforms the AF strategy in all suggested scenarios.

References

[1] J. Mitola and G. Q. Maguire, “Cognitive Radio: Making Software Radios More Personal,” IEEE Pers. Commun., vol. 6, 1999, pp. 13–18.

[2] IEEE 802.22 Working Group, “IEEE P802.22/D1.0 Draft Standard for Wireless Regional Area Networks Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands,” Apr. 2008. [3] A. Name, "Dissertation Title", M.S.(or Ph.D.) thesis, Department, University, City, Country, Year.

[3] Y. Zou et al., “An Adaptive Cooperation Diversity Scheme with Best-Relay Selection in Cognitive Radio Networks,” IEEE Trans. Signal Proc., vol. 58, no. 10, Oct. 2010, pp. 5438–45.

[4] J. N. Laneman et al., “Cooperative Diversity in Wireless Networks: Efficient Protocols and Outage Behavior,” IEEE Trans. Info. Theory, vol. 50, no. 12, Dec. 2004, pp. 3062–80.

[5] A. Ghasemi and E. S. Sousa, “Optimization of Spectrum Sensing for Opportunistic Spectrum Access in Cognitive Radio Networks,” Proc. IEEE CCNC ’07, pp. 1022–26.

[6] Y. Zou, Y.-D. Yao, and B. Zheng, “Cognitive Transmissions with Multiple Relays in Cognitive Radio Networks,” IEEE Trans. Wireless Commun., vol. 10, no. 2, Feb. 2011, pp. 648–59.

[7] G. Staple and K. Werbach, The end of spectrum scarcity,IEEE Spectrum, vol. 41,pp. 48–52, Mar. 2004.

[8] J. M. Peha, Approaches to spectrum sharing,[IEEE Commun. Mag., vol. 43,pp. 10–11, Feb. 2005.

[9] M. McHenry, E. Livsics, T. Nguyen, and N. Majumdar, XG dynamic spectrum access field test results,[IEEE Commun. Mag., vol. 45, pp. 51–57, Jun. 2007.

[10] FCC, BNotice of proposed rule making and order,[ET Docket 03-322, Dec. 2003.

[11] S.Haykin, Cognitive radio: Brain-empowered wireless communications,[IEEE J. Sel. Areas Commun., vol. 23, pp. 201–220, Feb. 2005.

[12] F. K. Jondral, Software defined radioVBasics and evolution to cognitive radio,[EURASIP J. Wireless Commun. Netw., no. 3, pp. 275–283, 2005.

[13] I. F. Akyildiz, W.-Y. Lee, M. C. Vuran, and S. Mohanty, Next generation/dynamic spectrum access/cognitive radio wireless networks: A survey,[Comput. Netw., vol. 50, pp. 2127–2159, 2006.

[14] A. Nosratinia, T. E. Hunter, and A. Hedayat, Cooperative communciation in wireless networks,[IEEE Commun. Mag., vol. 42, pp. 74–80, Oct. 2004

[15] D. Cabric, I. D. O’Donnell, M. S.-W. Chen, and R. W. Brodersen, Spectrum sharing radios,[IEEE Circuits Syst. Mag., vol. 6, no. 2, pp. 30–45, 2006.

[16] A. Sahai, N. Hoven, and R. Tandra, Some fundamental limits on cognitive radio,[in Proc. Allerton Conf., Monticello, Oct. 2004.

[17] A. Ghasemi and E. S. Sousa, Collaborative spectrum sensing for opportunistic access in fading environments,[in Proc. 1st IEEE Symp. New Frontiers Dyn. Spectrum Access Netw. (DySPAN), Baltimore, MD, Nov. 8–11, 2005, pp. 131–136.

[18] M. Gandetto and C. Regazzoni, Spectrum sensing: A distributed approach for cognitive terminals,[IEEE J. Sel. Areas Commun., vol. 25, pp. 546–557, Apr. 2007.