Chapter 24
Dual-Hop and Multi-Hop Cooperative Spectrum Sensing with an Improved Energy Detector and Multiple Antennae-Based Secondary Users

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ABSTRACT

A dual-hop cooperative spectrum sensing approach is studied in detail, where each cooperative Cognitive Radio (CR) makes a binary decision based on the local observation, by using an improved energy detector, and then forwards it to a common receiver. At the common receiver, all binary decisions are fused together. The authors provide an analytical framework for the analysis of performance of the improved energy detector-based cooperative CR network. They discuss how to choose an optimal number of cooperating CRs in order to minimize the total error rate by using an improved energy detector over perfect and imperfect reporting channels. Further, the error performance of dual-hop cooperative spectrum sensing with multiple antennae-based CR is discussed. The authors also exploit the multi-hop cooperative communication approach in an improved energy detector-based CR network for increasing the coverage area of the secondary communication systems with reduced power consumption.

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BACKGROUND

The need of spectrum resources will go on increasing as wireless technologies continue to grow in future and recent times. All available frequency bands are allocated to specific services and unlicensed users are not allowed to use them. Recently, Federal Communications Commission (FCC) has indicated that the actual licensed spectrum is not utilized properly for various time, frequency, and geographic locations (FCC, 2002). The secondary user (SU), i.e., unlicensed user, may utilize a licensed band when a primary user (PU), i.e., licensed user, is absent and its allocated frequency spectrum is free. To promote the efficient use of the spectrum, cognitive radio (CR) has been proposed in (Mitola & Maguire, 1999). A CR is able to use spectrum holes by sensing and adapting to the environment without causing harmful interference to the licensed users. In order to make efficient use of spectrum without causing interference to the PU, there is a need to make correct decision about the vacant frequency band. The CR technology enables the unlicensed user to use the licensed spectrum, when it is free. Although PUs have the priority of usage of the spectrum, most of the spectrum remain unused for a significant amount of time (Haykin, 2005). In a CR network, SUs have to decide on the absence of a PU in order to start transmission, and also have to leave the channel unoccupied when the PU starts data transmission.

Spectrum sensing is a mandatory functionality in any CR-based wireless system that opportunistically shares spectrum bands among the licensed primary services, such as the IEEE 802.22 standard (IEEE P802.22/D0.5, 2008). This CR related standard depicts the usage of the vacant spectrum in the TV broadcast bands. There has been a significant amount of study performed on the spectrum sensing for CR based network in (Ghasemi & Sousa, 2008; Akyildiz et al., 2008). Conventional energy detector (Urkowitz, 1967) is a useful non-coherent detector for signals corrupted by the Gaussian noise, which has been studied in (Letaief & Zhang; 2009, Zhang et al., 2009; Zhang et al., 2008; Zhang & Letaief, 2008; Herath et al., 2011; Rao & Alouini, 2011). It is shown in (Chen, 2010; Singh et al., 2011a, 2011b; Singh et al., 2012) that the performance of a single antenna based CR system can be improved, by utilizing an improved energy detector in each CR, where the conventional energy detector is modified by replacing the squaring operation of the received signal amplitude with an arbitrary positive power p. Multiple antennas for spectrum detection can be deployed in the CR to improve the detection performance of spectrum hole and to provide a high data rate and high efficiency broadband services by standards such as the Long Term Evolution (LTE), WiMax and IMT-Advanced. In (Pandharipande & Linnartz, 2007; Taherpour et al., 2010), it is shown that the linear combinations of multiple antenna outputs can be used to improve the reliability of spectrum sensing. Optimization of K-out-of-N fusion rule in cooperative spectrum sensing with conventional energy detector is discussed in (Althunibat et al., 2013). Basically two setups regarding maximizing the energy efficiency and minimizing the false decision probability have been considered. It has been shown in (Althunibat et al., 2013) that energy efficiency maximization setup significantly improves the network performance in terms of the achievable energy efficiency and the resulting interference. A CR network in a multi-hop communication scenario using an improved energy detector is studied in this chapter; whereas, only dual hop based cognitive communication system with a conventional energy detector is considered in (Zhang et al., 2008). The reporting channels between CR and fusion centre are assumed to be erroneous in this chapter instead of error free as considered in (Zhang et al., 2008). Also the role of multiple antennas in each CR is considered in this chapter; whereas, single antenna based CR is assumed in (Zhang et al., 2008).