Chapter 10
Spectrum Sensing and Throughput Analysis for Cognitive Radio: An Overview

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ABSTRACT

Cognitive radio (CR) is a new technology introduced to deal with the issues of spectrum scarcity and underutilization. Since the spectrum is limited, the unlicensed secondary users (CR users) opportunistically access the underutilized spectrum allocated to the licensed primary users (PUs) of the network. This chapter first gives a brief overview on spectrum sensing and its impact on the system throughput in a cognitive radio network. Later, cooperative relays are introduced in the network to improve spectrum efficiency and mitigate interference to PU. A detailed analysis of power allocation is demonstrated where the transmit power of CR is kept within such limit so that it can maintain low interference to PU. This optimal power allocation can achieve high throughput, which is also presented in this chapter.

INTRODUCTION

Cognitive radio is a promising new technology which provides the scope of a more reliable, flexible and efficient spectrum sharing scheme with better utilization of the radio spectrum using signal processing and adaptive procedures. As pointed out by Cabric et al. (2004), there is a spectrum scarcity at frequencies that can be economically used for wireless communications. A recent survey made by Federal Communications Commission's (FCC) Spectrum Policy Task Force (FCC, 2002) has shown that the actual licensed spectrum is largely underutilized in vast temporal

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and geographic dimensions. Indeed, if portions of the radio spectrum are scanned, it reveals that some frequency bands in the spectrum are largely unoccupied most of the time; some other frequency bands are only partially occupied while the remaining bands are heavily used. The underutilization of the electromagnetic spectrum leads us to a term *spectrum hole*, which is a band of frequencies assigned to a primary user (licensed) but at a particular time and specific geographic location, the band is not being utilized by the user.

Basically CR is an intelligent radio that can first perceive its radio environment through wide-band spectrum sensing and then adapts its transmission and reception parameters such as, the operating frequency, modulation scheme, code rate, and transmission power in real time with two primary objectives in mind: highly reliable communication whenever and wherever needed and efficient utilization of radio spectrum. CR improves the spectrum utilization by allowing secondary users to share the same licensed band allowed by the primary users. The secondary user or CR user first senses the spectrum band for any spectrum holes and if it finds one then it starts its transmission; otherwise it waits for the next time slot to repeat its actions. Coexistence of primary user (PU) and CR often leads to harmful interference to PU. In such a case spectrum sharing to the CR can only be allowed under tolerable interference limits. Cooperative relays can be used to mitigate the interference and improve spectrum utilization.

Two of the major functions of CR are sensing and transmit-power control. This chapter basically focuses on the transmit-power control of a relay assisted CR system. At first it gives a general idea of spectrum sensing and presents the tradeoff relationship between sensing time and cognitive system throughput. A study of optimal approach of power allocation is done to maximize throughput using subgradient method, a part of which is later modified with ellipsoid method that ensures faster convergence rate. Furthermore, an alternative iterative approach for power allocation and throughput maximization of the CR system is shown which provides a near-optimal performance but reduces the computational complexity significantly.

BACKGROUND

One of the main reasons for the birth of Cognitive Radio in the wireless world is to fight against the problems of spectrum scarcity (Haykin, 2005) and spectrum underutilization (Neel, 2006). On one hand the radio spectrum is scarce and on the other hand the licensed users do not use their spectrum fully which results in underutilization of the band (FCC, 2003a). To mitigate the problem of underutilization, unlicensed users better known as secondary users (SU) are introduced in the wireless network to utilize the unused band by the PU. The secondary users are also referred to as Cognitive Radios (CR) which was first introduced by Mitola and Maguire (1999).

CR's main task is to sense its operational electromagnetic environment and dynamically and autonomously adjust its radio operating parameters to modify system operation such as maximize throughput, mitigate interference, facilitate interoperability and access secondary market (Neel, 2006). To carry out these tasks cognitive radios are constructed from the next generation of software-defined radios (SDR) with the additional ability to sense its surrounding environment, to track potential spectra changes, and to adapt according to the findings (Ulversoy, 2010). SDR technology brings the flexibility, cost efficiency and power to drive communications forward, with wide-reaching benefits realized by service providers and product developers through to end users. So SDR is an ideal platform for the realization of CR as majority of CR functions will be implemented on modified software components that run on flexible and powerful processing.