Chapter 1

Hybrid Cooperative Energy Detection Techniques in Cognitive Radio Networks

Raza Umar  
King Saud University, Saudi Arabia

Fahham Mohammed  
King Fahd University of Petroleum and Minerals, Saudi Arabia

Mohamed Deriche  
King Fahd University of Petroleum and Minerals, Saudi Arabia

Asrar U. H. Sheikh  
The University of Lahore, Pakistan

ABSTRACT

Cognitive Radio (CR) has emerged as a smart solution to spectrum bottleneck faced by current wireless services under which licensed spectrum is made available to unlicensed Secondary Users (SUs) through robust and efficient Spectrum Sensing (SS). Energy Detection (ED) is the dominantly used SS approach owing to its low computational complexity and ability to identify spectrum holes without requiring a priori knowledge of primary transmission characteristics. In this chapter, the authors present an in-depth analysis of the ED test statistic. Based on the double threshold ED, they analyze the performance of a Hybrid PSO-OR (Particle Swarm Optimization and OR) algorithm for cooperative SS. The sensing decision of “fuzzy” SUs is optimized using PSO and the final collective decision is made based on OR rule. The idea of using two thresholds is introduced to reduce the communication overhead in reporting local data/decision to the fusion center, which also offers reduced energy consumption. The Hybrid PSO-OR algorithm is shown to exhibit significant performance gain over the Hybrid EGC-OR algorithm.

INTRODUCTION

Current spectrum allocation policy adopted by the government spectrum regulatory agencies provides each wireless service provider with a license to operate within a particular frequency band in one geographical location. With the focus shifting to new multimedia services, demand for higher bandwidth allocation has increased. As the radio spectrum is limited, the present scenario doesn’t allow the wireless systems to adapt to these fast changing demands. As a result, Federal Communications Commission (FCC) car-
ried out a number of studies to investigate current spectrum scarcity with the goal to optimally manage available radio resources. Recent measurements have revealed that a large portion of assigned spectrum is sporadically utilized. According to FCC (2003a) notice of proposed rulemaking and order, spectrum utilization varies from 15% to 85% with wide variance in time and space. This suggests that the root cause of current spectrum scarcity is not the physical shortage of spectrum rather it is inefficient fixed spectrum allocation. This fact questioned the effectiveness of traditional spectrum policies and opened doors to a new communication paradigm to exploit radio resources dynamically and opportunistically.

Dynamic and Opportunistic Spectrum Access (DOSA) is proposed to be the solution for inefficient spectrum utilization wherein unlicensed users are allowed to opportunistically access the un-used licensed spectrum under the stringent requirement of avoiding interference to the licensed users of that spectrum. In this way, the NeXt Generation (xG) wireless networks based on DOSA techniques are proposed to meet the requirements of wireless users over heterogeneous wireless architectures by making them intelligently interact with their radio environment. Cognitive Radio, which was first discussed in (Mitola & Maguire, 1999) is seen as an important technology that enables xG network to use the spectrum dynamically and opportunistically. The key component of CR technology is the ability to measure, sense and ultimately adapt to the radio’s operating environment. In CR terminology, the users with legacy rights on the usage of specific part of the spectrum are called primary users (PU) while the term secondary users (SU) is reserved for low-priority un-licensed users which are equipped with a cognitive capability to exploit this spectrum without being noticed by PU. Therefore, as identified by Raza Umar & Sheikh (2012), the fundamental task of SU (also termed as simply CR in literature) is to reliably sense the spectrum with an objective to identify a vacant band and to update its transmission parameters to exploit the unused part of the spectrum in such a way that it does not interfere with PU.

Being the focus of this chapter, we identify Spectrum sensing (SS) as the key cognitive functionality. Spectrum sensing in essence is the task of obtaining awareness about the spectrum usage at a specific time in a given geographical region. Intuitively this awareness can be obtained by using beacons or geo-location and database. These approaches though appear simple but are practically infeasible because of prohibitively large infrastructure requirements and implementation complexity. In this article we focus on local spectrum sensing at CR based on primary transmitter detection. To achieve spectrum efficiency, spectrum sensing must be performed by secondary users continuously to use the licensed band whenever the primary user is absent, however; it should also minimize interference with the PU (Raza Umar & Sheikh (2012b).

A review on spectrum sensing techniques for Cognitive Radio Networks (CRNs), with a special focus on sensing methods that need little or no information about the primary signals and the propagation channels, is presented in (Yonghong Zeng, Liang, Hoang, & Zhang, 2010). A comparative study of these schemes (Raza Umar & Sheikh, 2012a) reveals that energy detection (ED) is the most widely used spectrum sensing approach since it does not need any a priori information about the primary transmission characteristics, is easy to implement, and has low computational complexity while being optimal for detecting independent and identically distributed (IID) primary signals. Furthermore, the importance of ED based sensing is evident from the fact that most of the cooperative sensing techniques reported in the recent literature (Arshad, Imran, & Moessner, 2010; Saad, Han, Basar, Debbah, & Hjorungnes, 2011) employ ED for local detection of primary transmissions in addition to a variety of two-stage sensing schemes which perform at the first stage coarse detection based on ED (Maleki, Pandharipande, & Leus, 2010).