Chapter 16

Cooperative Cognitive Radio Networking: Towards a New Paradigm for Dynamic Spectrum Access

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ABSTRACT

Radio spectrum underutilization and energy inefficiency become urgent bottleneck problems to the sustainable development of wireless technologies. The research philosophies of wireless communications have been shifted from balancing reliability-efficiency tradeoff in the link level to seeking spectrum-energy efficiency in the network level. Global spectrum-energy efficient designs attract significant attention to improving utilization and efficiency, wherein cognitive radio networks and energy-efficient resource allocation are of particular interests. In this chapter, the authors first provide a systematic study on Cooperative Cognitive Radio Networking (CCRN). As an effort to shed light on addressing spectrum-energy inefficiency at a low complexity, an orthogonal modulation enabled two-phase cooperation framework and an Orthogonally Dual-Polarized Antenna (ODPA) based framework, as well as their resource allocation problems are given and tackled.

DOI: 10.4018/978-1-4666-6571-2.ch016
INTRODUCTION

During the past two decades, we have witnessed an explosive proliferation of applications in wireless communications and networking, e.g., vehicular ad hoc networks (VANETs), internet of things (IoTs), social networks, location-based services (LBSs), and smart grid. State-of-the-art technologies associated with products and services are changing our life styles from various aspects. While we are now enjoying the remarkable improvement in quality of service (QoS) provided by the fourth generation (4G) mobile communications networks, i.e., LTE-Advanced and WiMAX-Advanced, people from both academia and industry are seeking for the design of the next generation (xG) wireless networks, among them Wireless Vision 2020 plan towards 5G standard is notable (David, 2010).

To support sustainable development of wireless communications and networks, the demand for radio spectrum has been skyrocketing. Since the amount of usable spectrum is finite, frequency bands and their usage are strictly managed and enforced by government regulators. In the past decade, information and communication technologies (ICT) industry has turned into a highly competitive industry where companies are competing to buy valuable spectrum from governmental bodies, i.e., spectrum auction. In such a way, the winning telecommunications operators in spectrum bidding obtain the rights, also known as licenses, to transmit signals over specific bands of the electromagnetic spectrum and to conduct their communications services. With more services providers in the mobile industry, the competition during spectrum auctions has increased due to more demand from consumers and physical scarcity in available radio spectrum. In early 2013, for commercializing 4G networks, the United Kingdom government performed a spectrum auction for 250MHz of spectrum (equivalent to two-thirds of the entire 3G spectrum already in use) in the 800MHz and 2.6GHz bands. In total, five bidders have committed to pay 2.34 billion UK pounds for the right to use the frequencies for 4G services (Cao, 2013). According to a report from the Ministry of Industry and Informationization of China, China’s total spectrum demand in wireless communications is about 1GHz by 2015. However, 547MHz of spectrum has already been assigned for IMT systems, leading to 420MHz of spectrum scarcity, if no new spectrum is exploited (Cao, 2013).

On the one hand, we are now facing a challenging issue that physical spectrum scarcity hinders the further evolution of wireless communications. On the other hand, investigations and experiments on spectrum utilization have clearly shown that most of the allocated spectrum is considerably underutilized. Since the spectrum is exclusively assigned to dedicated users, termed as licensed or primary users (PUs), other users cannot access to the spectrum even if it is unused. This also imposes us a conflict between spectrum scarcity and spectrum underutilization, which further exacerbates the situation of spectrum shortage. New wireless applications and services along with emerging diverse wireless networking architectures, e.g., heterogeneous networks, have been severely hampered by this inefficient fixed spectrum allocation.

In order to address spectrum underutilization, dynamic spectrum access based schemes, which allow unlicensed users (or referred as secondary users (SUs)) to share or reuse licensed bands without interfering with PUs, have attracted significant attention (Goldsmith, 2009; Wang B., 2011; Wang J., 2011; Granelli, 2010; Akyildiz, 2006. Haykin, 2005). By enabling dynamic spectrum access, SUs are allowed to (i) dynamically sense the surrounding electromagnetic environments and opportunistically access to temporarily unused spectral bands, e.g., spectrum sensing based systems, (ii) concurrently and transparently transmit in licensed bands as long as PUs’ transmissions are not interfered, e.g., ultra-wide band (UWB) systems, or (iii) cooperatively and trustfully negotiate with PUs for transmission opportunities.
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