

# Chapter 11

## Spectrum Sensing in Cognitive Radio Networks

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### **ABSTRACT**

*The rising number and capacity requirements of wireless systems bring increasing demand for RF spectrum. Cognitive radio (CR) system is an emerging concept to increase the spectrum efficiency. CR system aims to enable opportunistic usage of the RF bands that are not occupied by their primary licensed users in spectrum overlay approach. In this approach, the major challenge in realizing the full potential of CR systems is to identify the spectrum opportunities in the wide band regime reliably and optimally. In the spectrum underlay approach, CR systems enable dynamic spectrum access by co-existing and transmitting simultaneously with licensed primary users without creating harmful interference to them. In this case, the challenge is to transmit with low power so as not to exceed the tolerable interference level to the primary users. Spectrum sensing and estimation is an integral part of the CR system, which is used to identify the spectrum opportunities in spectrum overlay and to identify the interference power to primary users in spectrum underlay approach. In this chapter, the authors present a comprehensive study of signal detection techniques for spectrum sensing proposed for CR systems. Specifically, they outline the state of the art research results, challenges, and future perspectives of spectrum sensing in CR systems, and also present a comparison of different methods. With this chapter, readers can have a comprehensive insight of signal processing methods of spectrum sensing for cognitive radio networks and the ongoing research and development in this area.*

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## 1. INTRODUCTION

Most of the current spectrum assignment rules in existing wireless communication networks around the world challenge the dynamic spectrum access aspects due to static RF spectrum assignment to the service providers for exclusive use on a long term basis. The exclusive spectrum licensing by government regulatory bodies, such the Federal Communications Commission (FCC) in the United States, and its counterparts around the world, is for interference mitigation among different service providers and their service users. However, the static spectrum assignment to particular service provider leads to inefficient use of spectrum since most portion of the spectrum remains under-utilization (Akyildiz et al., 2006). This implies that the scarcity of spectrum is not because of lack of natural spectrum but result of static spectrum allocation which leads to serious bottleneck for deployment of larger density of wireless systems. Advancements in integrated circuits and transceiver technology results in increasing demand of RF spectrum. Cognitive radio (CR) system is an emerging concept to increase the spectrum efficiency which uses the spectrum opportunities dynamically without creating harmful interference to licensed users. CR system may have two situations. One is with both licensed primary users and unlicensed secondary CR users occupying the same spectrum like in licensed band scenarios. The next situation is with no primary users and every CR user contends for spectrum with other CR users and non-CR users as in the unlicensed band scenario. In this paper, we deal with the situation where primary and secondary CR users are active, and the aim is to present signal processing techniques for spectrum sensing to avoid the disturbance to primary user transmissions while CR users use the band dynamically.

The dynamic spectrum access for spectrum sharing in CR systems has two basic approaches (Akyildiz et al., 2006, Haykin, 2005). One is *spectrum overlay* technique whereby a unlicensed CR

users require to sense and identify the spectrum opportunities in licensed bands before using them for given time and geographic location, and exploit those opportunities dynamically. Whenever the primary users are active in given frequency band for given time and location, secondary CR users are not allowed to use that band. Once they find the spectrum opportunities they can use those opportunities dynamically until the primary systems want to use them and the CR users have to leave the band as quickly as possible (Poor, H.V. and Hadjiladis, O., 2009, Haykin, 2005). The other is *spectrum underlay* approach where secondary CR users coexist and transmit simultaneously with primary users sharing the licensed bands but CR users are not allowed to transmit with high power as they have to respect the active primary user transmissions. In this approach, secondary CR users do not have to sense the spectrum for opportunities however they are not allowed to transmit with higher than the preset power mask even if the primary system is completely idle. It is worth to note that the main goal in both approaches is to access the licensed spectrum dynamically and/or opportunistically without disturbing the primary user transmissions. In spectrum overlay approach, the major challenge to realize the full potential of CR systems is to identify the spectrum opportunities in the wide band regime reliably and optimally. And in spectrum underlay approach, the challenge is to transmit with low power so as not to exceed the tolerable interference level at primary users.

In order to realize the full potential of CR system, the detection of primary user signal is of vital importance (Rawat and Yan, 2009, Rawat and Yan, 2011). Generally, in CR system, devices detect each other's presence as interference and try to avoid the interference by changing their behavior accordingly. For CR systems, different techniques for spectrum sensing have been proposed in the literature to identify the spectrum opportunities for CRs. (Zeng and Liang, 2009, Cabric et al., 2006, De and Liang, 2007, Tang, 2005, Cabric

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