Chapter 27
Sensing Coverage and Connectivity in Cognitive Radio Sensor Networks

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ABSTRACT

Sensing coverage of a field of interest and connectivity are two very important performance measures in Wireless Sensor Networks (WSNs). Existing design methodologies and protocols for enhanced field sensing coverage and connectivity in WSNs are not directly applicable to Cognitive Radio Sensor Networks (CRSNs) due to their cognitive nature. In this chapter, the authors first review sensing coverage and connectivity models for traditional WSNs. Then, they propose novel approaches for sensing coverage and connectivity establishment in CRSN, benefiting from useful existing models from WSN and Cognitive Radio Ad Hoc Networks (CRAHNs). Proposed approaches span a wide variety of CRSN requirements and also point out open research problems in the field to guarantee sufficient sensing coverage quality and connectivity in CRSN.

INTRODUCTION

Recent advances in microelectromechanical systems, signal processing and wireless communications have made it possible to manufacture low cost, low complexity wireless sensor nodes. These nodes, called wireless sensor nodes, are capable of sensing their environment, processing the sensed data if needed, and transmitting the sensing data toward the *data fusion center* (also known as the *sink).* A collection of wireless sensor nodes, which sense a field of interest and report their data to the sink are called a Wireless Sensor Network (WSN).

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A WSN consist of a large number of nodes deployed in the area of interest. The locations of nodes within this area may be predetermined and engineered, or may be totally random. These deployed nodes are composed of four basic units: *Sensing unit*, *processing unit*, *transceiver unit* and *power unit*. A wireless sensor node monitors its environment thanks to its sensing unit. The transceiver allows a wireless sensor node to communicate its sensed and possibly processed data to other nodes. The power unit provides the power required for sensing, communication and processing tasks. The sensor node may decide to process the sensed data to obtain a useful piece of information and transmit it to the intended node or to the sink, instead of sending the raw sensing data.

Application areas of WSNs cover a wide range of topics, including but not limited to military applications, environmental monitoring, healthcare and industrial applications. For instance, in a military setting, a WSN deployed as a thin strip to a country's border can serve to detect intruders, whereas a WSN deployed over the large area of a forest can do periodic monitoring and provide early warning when fires outbreak. A wide range of applications, as well as factors affecting WSN design are thoroughly investigated in Akyildiz (2002).

Two main challenges faced by WSNs are communication of sensing data to the sink in a timely manner, and to do this communication under the resource constraints, especially the limited power. WSN nodes need to carry out sensing, communication and data processing tasks under the constraint of limited battery power. Since WSN nodes are both data generators and forwarders of other nodes' data to the sink, communication related power consumption has to be kept at an optimal level during network design, for enhanced network lifetime.

In WSN, nodes are communicating to each other via wireless medium. Although infrared and optical communications are also possible, WSN nodes usually benefit from wireless radios for communication. WSNs often operate on the Industrial, Scientific and Medical (ISM) bands for communication purposes. However, these bands are becoming fast overcrowded due to many networks of diverse set of applications going live on them. To this end, WSNs need to compete with other networks that operate on these bands for access to frequency medium, creating spectrum scarcity issues.

WSNs suffer from communication and constrained power source challenges in the following manner: In case of event detection within the field of WSN, nodes that detect the event consequently generate packets and race among them and also with other networks they are overlaid with for access to frequency spectrum. Due to collisions, nodes may have to retransmit their packets several times, causing excessive energy consumption. It may even be the case that packets related to the event may not make it to the sink in a time interval that would make their contents significant and valuable for consideration.

The spectrum scarcity problem is envisaged to be addressed by *Dynamic Spectrum Access* (DSA) schemes. Cognitive Radio (CR) is the key enabling technology to provide dynamic, i.e. opportunistic, spectrum access. With CR capabilities, communicating parties can sense the spectrum, determine the vacant spectrum bands and use them for their operations. In that sense, CR devices can also use the licensed bands opportunistically in addition to unlicensed bands, hence ameliorating the spectrum inefficiency problem of traditional fixed spectrum access schemes. CR users, called Secondary Users (SUs) can use the licensed bands as long as they do not interfere with the transmission of licensed band users, i.e. Primary Users (PUs).

Governmental agencies regulate the spectrum usage and licenses. The fixed spectrum portions are assigned to the license holders over certain geographical regions. In this type of fixed spec-