Chapter 8
Network Layer for Cognitive Radio Sensor Networks

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ABSTRACT

Based on recent trends, Cognitive Radio paradigm has become an integral part of future communication networks of which Wireless Sensor Network is an integral part. However, Cognitive Radio (CR) introduces critical issues that have to be addressed for communication in networks to be achieved. Routing, being the core of communication, has to be critically examined within the context of Cognitive Radio Sensor Networks. In this chapter, the authors discuss relevant issues on the topic of routing in Cognitive Radio Sensor Networks (CRSN). As a basis, a general overview of routing in the Wireless Sensor Network (WSN) is made. The applicability of these protocols in CRSN is discussed and the need for integrating Opportunistic Spectrum Access components into existing Wireless Sensor Network protocols is exposed. Factors affecting routing in CRSN are outlined with an emphasis on a cross layering design approach based on a generalized framework. Recent works in this respect are categorized, and finally, open issues in need for research attention are pinpointed.

INTRODUCTION

Wireless Sensor Networks consist of sensor nodes having the ability of sensing an event and transmitting same wireless via multi-hopping to a collection center referred to as the sink. They are usually deployed in an ad-hoc (self-organizing) manner with fixed spectrum allocation and are characterized with having communication, energy, computational and memory constraints. For example, a typical wireless sensor node can have a memory of 128Kb – 1Mb, which is regarded small. The embedded processor is also usually an 8bit 10MHz processor. The transceiver which is operated on a fixed channel mode in any of the channels of the industrial, scientific and medical (ISM) band, can achieve a data rate range between 1kbs – 1Mbs and a communication distance of 3-300 meters. The operating batteries are usually expected to run for about two years or more depending on the mode of operation. Table 1 and 2 shows some basic operational characteristic of some commercial wireless sensor nodes.

Usually, except in special cases, sensor networks are designed for specific applications. Thus, depending on the application, each node can serve as both data source and as a router. The application area of wireless sensor network (WSN) spans over very diverse fields ranging from military, wildlife and agriculture, emergency, disaster and extends to the future Internet of Things (Xu, 2002).

On the other hand, a cognitive radio sensor network (CRSN) is defined as a distributed network of wireless cognitive radio sensor nodes that sense an event signal and collaboratively communicate their readings dynamically over the available spectrum bands in a multi-hop manner to satisfy application-specific requirements. By implication, CRSN inherits all the basic characteristics of WSN and differs from WSN in that each node in CRSN is fitted with a cognitive radio (CR). Thus, any sensed event signal is collaboratively communicated dynamically over available spectrum bands in a multi-hop manner unlike in WSN in which all nodes operate on a specific channel which is set before deployment. A typical illustration of a CRSN is depicted in Figure 1.

The CRSN paradigm was brought about as a result a number of issues some of which are; a) congestion of the ISM (Cavalcanti, Schmitt, & Soomro, 2007; Howitt & Gutierrez, 2003; Zhou, Stankovic, & Son, 2006), b) degradation of service due to interference from neighboring wireless systems like WiMAX, Bluetooth and Wi-Fi that also operate these bands just as applications like cordless phones and microwave devices (Garroppo, Gazzarrini, Giordano, & Tavanti, 2011; Haron, Syed-Yusof, Fisal, Syed-Ariffin, & Abdallah, 2008; Pollin, Tan, Hodge, Chun, & Bahai, 2008) and c) underutilization of the spectrum below 3GHz, in other words, the presence of white space (Commission, 2003).

Although the CR can mitigate the above-mentioned problems (Cavalcanti, Das, Wang, & Challapali, 2008), it, however, introduces unique challenges into WSN networking and communication. In other words, CR introduces a major change in the design for all communications protocols. Hence the MAC, Network, Transport and Application layers have to be designed to meet the requirements of Dynamic Spectrum Access (DSA)/ Opportunistic Spectrum Access which CR introduces into the network. Details on how CR affects the interlayer interaction are discussed under the section of cross-layering. In this regard, the CR is supposed to enhance WSN with dynamic spectrum access so that node's access media in an opportunistic manner to intelligently maximize channel usage while significantly reducing harmful interference. Another advantage of the CR is its capability of bandwidth aggregation (Shah & Akan, 2013) which makes it suitable for the real-time data which is generally, the common trend of recent networks.

The fact that the Network Layer is very vital to any network (Akyildiz & Vuran, 2010b) calls for special research attention to tackle the issues arising in the Network layer as a result of the

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