# Cognitive Radio Sensor Networks

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## 1. INTRODUCTION

Lot of research work and technological developments have been done in the domain of Wireless Sensor Networks (WSNs). These WSNs have tremendous application areas ranging from health care, mining, intrusion detection, environmental monitoring, home automation, forest fire detection, and wild life tracking, to monitoring structure of the high rise buildings. In fact, WSNs use fixed spectrum assignment policy but since most of the spectrum has already been assigned to users, therefore a problem of spectrum scarcity arises. Also, their performance is limited due to limited communication and processing power of wireless sensor nodes. Additionally, wireless sensor networks require high bandwidth and their Quality of Service (QoS) requirements are application specific. On the other hand, Cognitive Radio Network (CRN) is proposed to solve the problem of spectrum scarcity by opportunistic utilization of licensed spectrum (fixed spectrum) when it is not in used by the licensed users (Primary users or PUs). Cognitive radio devices are intelligent devices which can change their transmission parameters based on their operating environment. Thus, in order to solve the challenges of wireless sensor networks, the idea of using wireless sensor nodes with cognitive radio technology i.e., Cognitive Radio Sensor Networks (CRSNs) is proposed in the recent years. CRSNs can improve the spectrum utilization, and multiple overlaid sensor networks can be deployed in a specific region. Since it is an emerging technology, therefore, it has several research problems which need to be addressed. The main objective of this article is to provide an overview of Cognitive Radio Sensor Networks, their potential application areas, architecture, and future directions and challenges.

## 2. BACKGROUND

Traditionally, wireless networks follow fixed spectrum assignment policy, regulated by the government. The spectrum is assigned to users, who pay for the assigned spectrum for specific time and frequency. These users are called licensed users (Primary Users or PUs). This policy worked well in the past but now, with the passage of time, most of the spectrum has been assigned to licensed users and very less spectrum is remained. On the other hand, with the advancement in technology, there is a drastic increase in the development of new devices (e.g., smartphones, PDAs, tablets etc.) which operate on unlicensed spectrum. Therefore, the unlicensed spectrum has become overcrowded. Due to these two issues, a problem of spectrum scarcity arises. However, according to the survey, licensed users do not use their assigned spectrum all the time. Hence there is much sparsity in the utilization of licensed (fixed assigned) spectrum bands which resulted in underutilization of licensed spectrum. It is observed that the utilization of licensed spectrum ranges from 15%-85% with high variance in time and location (Akyildiz et al., 2006). Thus, in order to solve the problem of spectrum scarcity, the Federal Communications Commission (FCC, 2003), a regulatory authority in USA has allowed the usage of licensed spectrum by unlicensed devices; subject to the condition that licensed user should not be interfered. Consequently, CRNs are proposed to solve the problem of spectrum scarcity. They exploit Dynamic Spectrum Access (DSA) technique in order to access multiple licensed spectrum bands dynamically. CRNs are composed of CR devices, which opportunistically utilize white spaces in licensed channels. White spaces are the spectrum which is not in use of licensed user for specific time and frequency. Also, CR devices are

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intelligent devices which can change their parameters based on the interaction with their operating environment (Akyildiz et al., 2009).

On the other hand, a WSN is composed of resource constraint sensor nodes which have limited resources of energy and power. They are deployed densely in the observing environment. WSNs follow fixed spectrum assignment policy; therefore they also suffer from spectrum scarcity problem. Thus, WSNs can exploit CR technology in order to solve the problem of spectrum scarcity. This integration of WSNs and CR technology will improve network performance, spectrum utilization and resource utilization (communication and processing) in WSNs. Sensor nodes in WSNs, equipped with CR technology form Cognitive Radio Sensor Network (CRSN) (Akan et al., 2009).

In CRSN, sensor nodes utilize DSA technique and operate on different spectrum bands because if a spectrum band is available at current time, then it might not be available at next time slot and thus sensor nodes can opportunistically exploit other available spectrum bands. The exploitation of CR technology reduces energy consumption by reducing number of retransmissions and improves the overall network performance by reducing packet loss rate due to opportunistic utilization of spectrum bands. The incorporation of CR technology in sensor nodes imposes some challenges of reliability and congestion control which are investigated by Bicen et al. (2011). For delay-sensitive and multimedia communications in CRSNs, main design challenges and principles are discussed in (Bicen et al., 2012).

## 3. COGNITIVE RADIO SENSOR NETWORK ARCHITECTURE

Cognitive radio sensor network is comprised of CRSN node, sink, primary user (PU) and PU base station. CRSN nodes transmit their collected data opportunistically to other sensor nodes for relaying and ultimately delivering to the sink based on spectrum availability. The sink may also be equipped with CR technology. Besides exchanging collected events information, sensor nodes also exchange control information with sink for spectrum allocation, PU activity detection and spectrum hand-off events.

Beside main architecture, it is also important to know about CRSN node architecture and topology which are explained below:

### 3.1. Node Architecture

CRSN node differs from traditional wireless sensor node in-terms of cognitive radio transceiver. This transceiver consists of RF front-end, demodulator and decoder. The cognitive radio capability enables dynamic configuration of communications parameters such as transmission range, carrier frequency, modulation etc. The architecture for CRSN node is illustrated in Figure 1, which is inspired by Akan et al., (2009).

### 3.2. Topology

CRSN topologies can be classified into four types based on application requirements (Akan et al., 2009).

#### 3.2.1. Ad-Hoc Architecture

Ad-hoc architecture is the most common architecture of CRSN. In this architecture, sensor nodes transmit their collected information to sink in a multi-hop manner. It has the least communication overhead for control data.

#### 3.2.2. Mobile Architecture

Mobile architecture creates dynamicity in CRSN in addition to PU activity. In mobile topology, CRSN nodes are mobile which create another complexity of topology management. Due to mobility of nodes, the probability of route breakage increases which requires immediate route maintenance mechanism. Thus due to sensor nodes mobility, it is important to design mobility-aware solutions for spectrum selection and route formation as well as to consider the challenges of mobile node development and deployment strategies.

#### 3.2.3. Clustered Architecture

In-order to exchange control information among sensor nodes and sink, it is important to have a common control channel so that all nodes will be tuned to that channel for control information exchange. Since CRSN operates on licensed spectrum, therefore a single spec-