Preface

Wireless Sensor Networks (WSNs) have tremendous applications ranging from health monitoring, wildlife tracking, air pollution monitoring, to the use of sensor networks for gully pot monitoring in urban areas. Wireless sensor network-based emerging technologies are also evolving. These emerging technologies are Internet of Things (IoTs), Vehicular Sensor Networks, Smart Grid, Cyber Physical System, Cloud Computing, and many others. Due to these enormous applications and use of WSNs in conjunction with different technologies, dense deployment of sensor nodes is required.

Currently, WSNs are deployed in ISM band and normally use fixed spectrum assignment policy. It is worth mentioning that different types of wireless networks such as Bluetooth and WiFi are also using the same ISM band. Furthermore, the bandwidth requirement of sensor nodes varies from application to application. Thus, considering these aforementioned facts and requirements, a new paradigm is evolving in which wireless sensor nodes are equipped with cognitive radio capability. This new paradigm is known as Cognitive Radio Sensor Networks (CRSNs).

Akan, Karli, and Ergul (2009) define cognitive radio sensor networks as:

A distributed network of wireless cognitive radio sensor nodes, which sense event signals and collaboratively communicate their readings dynamically over available spectrum bands in a multi-hop manner to ultimately satisfy the application-specific requirements.

Sensor nodes with cognitive radio capability in CRSNs have several advantages over the traditional WSNs. This includes dynamic spectrum access, opportunistic use of channels by the sensor nodes for bursty traffic, communication under different spectrum regulations, and the adaptability of sensor nodes to change their transmission parameters. Moreover, after integration of cognitive radio capability with sensor nodes, overlaid deployment of multiple wireless sensor networks is now possible.

Since cognitive radio sensor network is an emerging technology, these challenges and requirements need to be addressed by the research community. In this regard, new protocols and architectures have been proposed by the researchers around the world. However, there was not a single book available that could serve as a basis to help the readers to understand different layers of CRSNs, challenges associated with those layers, and future research directions. In this regard, this book is an effort to gather the developments that have been done so far in the domain of CRSNs. It can be used by researchers who want to start research in the domain of CRSNs. In addition, it can be used as a reference textbook for a senior undergraduate course or a graduate-level course on telecommunication and wireless networks, offered in Computer Engineering, Electrical Engineering, and Computer Science programs.

We now discuss the organization of this book. This book is composed of 11 chapters that are divided into 5 sections.
SECTION 1: PHYSICAL LAYER

First section of this book contains three chapters that focus on issues related to the physical layer aspects of cognitive radio sensor networks. It discusses the distinct features of CRSNs due to which existing sensing coverage and connectivity models designed for typical WSNs cannot be used in the cognitive environment. Next, this section provides a state-of-the-art review of the radio resource management techniques proposed in the context of CRSNs. Then, this section highlights the spectrum-sensing techniques that can be utilized in CRSNs.

Chapter 1 highlights the issues due to the varying nature of connectivity in CRSNs, existing techniques of sensing coverage, and why connectivity designed specifically for WSNs cannot be applied to CRSNs. In this context, existing models of sensing coverage and connectivity designed for traditional WSNs are discussed with the focus on the reasons they cannot be adopted in CRSNs. Then, based on the unique highlighted requirements of the CRSNs, novel approaches for solving sensing coverage and connectivity issues are proposed.

Chapter 2 provides an extensive overview of advances in radio resource management for CRSNs. It starts by highlighting the key reasons efficient radio resource management is required. Then, it provides a detailed classification of the existing radio resource management techniques and analyzes each classified group from the point of view of efficiency of energy, fairness and utilization of spectrum allocation, QoS assurance, interference mitigation, and spectrum hand-offs.

Chapter 3 discusses the issue of spectrum sensing in CRSNs with the aim of describing how helpful the dynamic spectrum access of CRs can be for them if efficient spectrum-sensing techniques are used. First, it provides an overview of the spectrum-sensing schemes proposed for traditional WSNs and discusses why they cannot be used in CRSNs. Then, this chapter provides an overview of the potential spectrum-sensing techniques that may be feasible for utilization in CRSNs. At the end, this chapter discusses open issues and challenges that have to be addressed for efficient spectrum-sensing mechanisms.

SECTION 2: MAC LAYER

This section contains three chapters that focus on the issues related to the Medium Access Control (MAC) Layer in the context of CRSNs. It discusses the distinct requirements that need to be incorporated in the MAC solutions in order to be used in combination with CRs. Then, it discusses different bandwidth allocation mechanisms in the light of the bandwidth requirements of the CRSN applications.

Chapter 4 addresses the issue of energy-efficient Medium Access Control for CRSNs. It proposes a novel Medium Access Control mechanism named CR-WSN MAC for CRSNs, which uses asynchronous duty-cycle technique for getting access to the channel and transmitting data. Performance evaluation via simulations shows that the proposed mechanism outperforms MCMAC protocol.

Chapter 5 highlights the possibility of a new channel and bandwidth selection paradigm for CRSNs in light of the bandwidth requirements of WSN applications. Currently, WSN technologies have a fixed spectrum allocation policy that results in inefficient spectrum usage because some applications like temperature and pressure monitoring require less bandwidth, whereas others like multimedia WSNs have higher bandwidth requirements. In order to improve spectrum utilization, this chapter provides an insight about the possibility of using variable spectrum allocation by bonding adjacent physical channels. It also discusses in detail the challenges and constraints of employing physical channel bonding in CRSNs.
Chapter 6 provides a detailed overview about how the software-defined radios can be used in the Cognitive Radio environments to opportunistically enhance spectrum utilization by configuring the network parameters according to the requirements of the communicating devices. It discusses in detail the existing software-defined radio architectures and highlights the challenges faced in their development and deployment.

SECTION 3: NETWORK LAYER

This section contains two chapters that discuss the issues that arise at the network layer in CRSNs. This section provides an extensive overview of the existing communication mechanisms in CRNs and WSNs with an aim to highlight the common ground on the basis of which the two technologies can be merged, in order to employ CRSNs and make networking in them possible.

Chapter 7 presents a very detailed insight about the challenges and open issues that need to be addressed in order to come up with efficient networking mechanisms for CRSNs. It discusses in detail how the networking platforms for the existing WSNs and CRNs have currently been framed while focusing on the similarities and differences between the two paradigms and tries to identify the common ground where both technologies could benefit from each other.

Chapter 8 provides an overview of the issues related to routing and highlights the problems due to which routing mechanisms proposed for fix spectrum allocation-based WSNs are infeasible in the dynamic spectrum access environment of CRSNs. Based on the requirements of the CRSN environment, this chapter proposes a cross-layer approach as a feasible solution for designing protocols and also provides a general framework model on the basis of which future protocols can be devised.

SECTION 4: TRANSPORT LAYER

This section focuses on the issue of reliable and energy-efficient data delivery at the transport layer of CRSNs. It gives an overview of the transport protocols designed for WSNs and CRNs and discusses the limitations in these protocols due to which transport layer solutions exclusive to CRSN requirements should be developed.

Chapter 9 highlights the issues and challenges in designing efficient transport layer protocols for CRSNs. First, it focuses on the challenges and issues that should be considered while designing efficient mechanisms. Then, based on the presented challenges and issues, it provides a foundation in the form of guidelines on the basis of which future transport layer solutions should be developed.

SECTION 5: APPLICATIONS

Chapter 10 sheds light on the applications and utility of independent component analysis for blind-source separation in WSNs, CRNs, and CRSNs. It discusses the challenges and issues that arise when independent component analysis is employed in CRSNs by combining ICA techniques employed currently in WSNs and CRNs.
Chapter 11 discusses the possibility of integrating CRSN applications with cloud computing. It highlights the applications of WSNs and discusses how the limited capacity of existing wireless sensor nodes in terms of storage, processing, computational speed, security, and bandwidth limit their utility. Then, it discusses a new paradigm—cloud computing—which offers powerful services/resources in terms of processing, computational speed, storage, and security, and gives an idea about the integration of CRSNs with cloud computing as complementing technologies.

In conclusion, this book offers knowledge about cognitive radio sensor networking approaches on all layers of the OSI Model with the aim of imparting maximum knowledge to the readers.

*Mubashir Husain Rehmani*  
*Department of Electrical Engineering, COMSATS Institute of Information Technology, Pakistan*

*Yasir Faheem*  
*Department of Computer Science, COMSATS Institute of Information Technology, Pakistan*

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**REFERENCES**