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Cognitive radio sensor networks: Smart communication for smart grids—A case study of Pakistan

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ABSTRACT

A smart grid has recently gained significant attention as it is an important direction of power system advancement. The integration of renewable energy (RE) resources to the power system and the reduction of energy losses need an efficient and low-cost communication infrastructure. Cognitive radio sensor networks (CRSN) can be integrated in a smart grid to meet these challenges. CRSN is a new paradigm of research where the best of wireless sensor networks (WSN) and cognitive radios (CR) is combined. The sensor networks monitor a physical parameter and the measures value is transmitted using the cognitive radio. Thus, CRSN can be used for realizing the sensing and communication part in a smart grid network. In this paper, a smart grid network is proposed using CRSN for implementing it in the remote areas of Pakistan. The service coverage map is taken from the Pakistan Telecommunication Authority (PTA) website that regulates the spectrum band in Pakistan. This can be used in developing countries to realize a cost effective smart grid for integrating the renewable resources and for reducing energy losses.

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1. Introduction

A smart grid can be efficiently realized by integrating communication technologies. The smart grid has the ability to communicate with its end devices in real-time that can lead to the efficient integration of RE resources and energy loss reduction. One such communication and sensing network is CRSN that is realized by combining the best of WSNs and cognitive radios.

The cost of WSNs is determined by many factors that include transmission power, processors operating frequency and memory. These networks are deployed in a number of applications including environmental sensing, battlefield monitoring, and forest fire detection [1]. Due to emerging applications, the use of WSNs is expected to increase in future. One of the fundamental requirements of WSNs is to increase the lifetime of resource-constraint sensor nodes. Sending a large amount of data in a timely fashion by WSN requires to send it simultaneously with minimal interference. This leads to higher power efficiency of the overall network. These requirements need to use a cognitive radio network where the abundant resources are used by the wireless sensor node [2].

The technology for cognitive radio (CR) [3–5] is promising for spectrum utilization by providing a technique for power efficiency [6]. This concept was first introduced by Mitola and Maguire [5] to efficiently use the available spectrum. The spectrum which is not fully used by a licensed used (primary user) may be used by the secondary user, without disturbing the primary user. There might be a number of available spectra among the licensed band and the secondary user can access the best available spectrum without causing interference to the primary user. This will increase the spectrum efficiency of the network.

The classical WSN system is characterized by a fixed frequency spectrum [7] and this concept may be used in WSNs for enhancing the network performance. Often a bursty traffic is generated in WSN that increases the chances of collision and the packet loss. Recent works such as Akan et al. [7] propose the application of cognitive radio wireless sensor networks (CRSNs). It is assumed that each sensor node has a cognitive radio. The sensor device selects the best available channel from the available spectrum band and it leaves the channel once the primary user starts its transmission. There might be a number of sensor nodes that may access the same band at the same time. Thus, there is a need for an efficient channel allocation mechanism for all the sensor nodes.

There are a number of new application areas in WSN including medical monitoring and industrial control that may send data at higher rates in real-time. These applications may need to communicate as a secondary user by utilizing a licensed band [8]. For example, smart grids for power systems may be realized using a WSN [9]. There are a number of renewable energy resources that may be used to decrease the overall cost of electricity. There is a need to design an effective control system for efficiently using the generated energy by minimizing the electricity fluctuations and catastrophic events. The key design challenge is to reliably and timely deliver the sensed data using the sensor devices that are installed on various sites so that an efficient decision can be made [10]. In order to meet that challenge, employed WSNs can use the CRSN for realizing a smart grid application.

Based on the above-mentioned discussion, this paper proposes an infrastructure for realizing cognitive radio sensor networks for the smart grid application. Then, a case study is proposed for the implementation of smart grid in Pakistan using the communication coverage data available from the Pakistan Telecommunication Authority.

The paper is organized as follows. Section 2 gives an overview of the electrical and smart grid networks while Section 3 discusses the communication technologies for a smart grid. Section 4 presents an overview of the renewable sources and Section 5 explains the standard classification of WSN. In Section 6, a brief overview of CRSN node architecture is presented. Section 7 proposes the application of CRSN in smart grid networks while Section 9 presents a case study of the proposed smart grid network in Pakistan. Finally, Section 10 concludes the paper.

2. Electrical grid and smart grid

The meaning of smart grid varies for different people who are looking at it from different perspective. In this section, a short overview of conventional power grid is presented. Afterwards, the