A Survey on Cognitive Radio Wireless Sensor Networks

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***Abstract* - A cognitive radio wireless sensor network is major areas where cognitive techniques can be used for opportunistic spectrum access. Research in this area is still in progression The aim of this study is to classify the existing literature of this fast emerging potential application area of cognitive radio wireless sensor networks and indicate open problems and Research Trends and Open Research Issues**
***Keywords* - sensor networks; cognitive sensors; cognitive wireless sensor networks**

I. INTRODUCTION

1.1 Cognitive Radio

Cognitive Radio (CR) is a paradigm for wireless communication in which either a network or a wireless node changes its transmission or reception parameters to communicate efficiently avoiding interference with licensed or unlicensed users. This alteration of parameters is based on the active monitoring of several factors in the external and internal radio environment, such as radio frequency spectrum, user behavior, and network state. The idea of CR was first proposed by Joseph Mitola III and Gerald Q. Maguire. It was thought of as an ideal goal towards which a *Software-Defined Radio (SDR)* platform should evolve: a fully reconfigurable wireless black-box that automatically changes its communication variables in response to network and user demands.

Software Defined Radio (SDR) has now reached the level where each radio can perform beneficial tasks that help the user, help the network, and helps to minimize spectral congestion. A simple example is the adaptive digital European cordless telephone (DECT) wireless phone,which finds and uses a frequency within its allowed plan with the least noise and interference on that channel and time slot. Three major applications that raise an SDR's capabilities and make it a *cognitive radio*:

1. Spectrum management and optimizations.
2. Interface with a wide variety of networks and optimization of network resources.
3. Interface with a human and providing electromagnetic resources to aid the human in his or her activities.

Cognitive radio can be defined as:

A "Cognitive Radio" is a radio that can change its transmitter parameters based on interaction with the environment in which it operates. A "Cognitive Radio" is an SDR that is aware of its environment, internal state, and location,and autonomously adjusts its operations to achieve designated objectives."

The cognitive radio is able to provide a wide variety of intelligent behaviors. It canmonitor the spectrum and choose frequencies that minimize interference to existing communication activity

The cognitive radio may also exhibit behaviors that are more directly apparent to the user:

1. awareness of geographic location,
2. awareness of local networks and their available services,
3. awareness of the user and the user's biometric authentication to validate financial transactions, and
4. Awareness of the user and his or her prioritized objectives.

1.2 wireless sensor networks

After the internet wireless sensor networks is second biggest network in the world so wireless sensor networks (WSNs) are becoming a hot area of global concern Communications in wireless sensor networks (WSNs) are event driven. Whenever an event triggers wireless sensor (WS) nodes generate bursty traffic. In a dense network environment, wireless sensor nodes deployed in the same area might try to access a channel whenever an event occurs. Recently, many sensitive and critical activities are being monitored and observed increasingly using WSNs. Several heterogeneous WSNs can exist, which causes a long waiting time for the delay sensitive data. Wireless sensors are normally deployed in inaccessible terrain. Therefore, the self-organizing ability and lifetime of the WS nodes are very important.

WSNs consist of hundreds of WS nodes deployed throughout the sensor field and the distance between two neighboring WS nodes is generally limited to few meters. A sink node or base station is responsible for collecting the data from the WS nodes in single or multiple-hop manner. The sink node then sends the collected data to the users via a gateway, often using the internet or any other communication channel. Figure 1 shows the scenario of conventional WSNs.

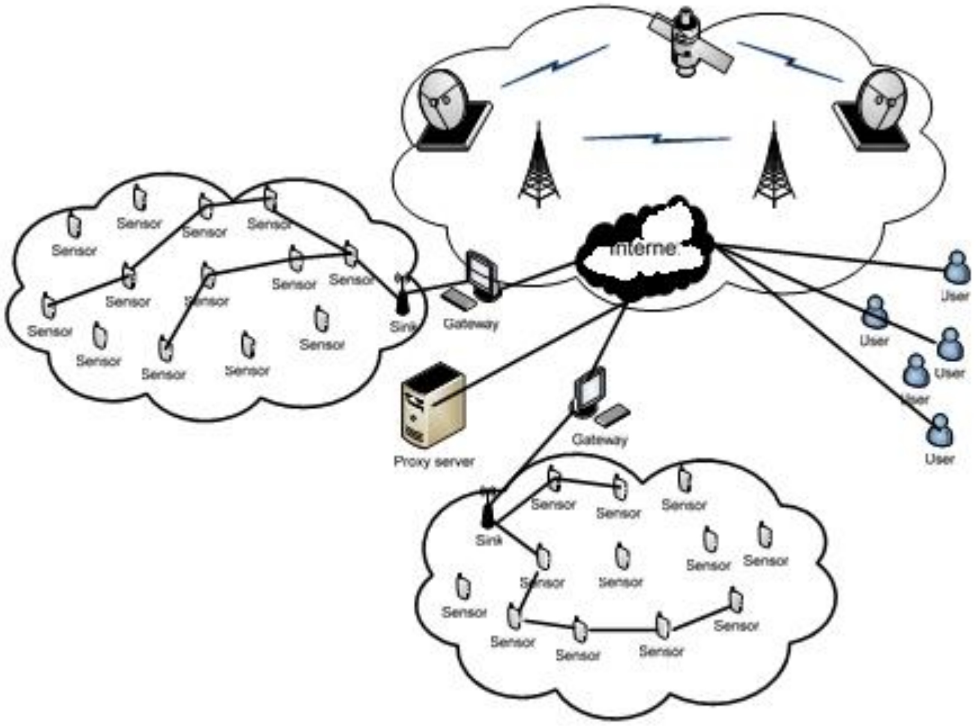

Figure 1. Conventional wireless sensor networks

Current WSNs operate in the ISM band, which is shared by many other successful communication technologies. Research has shown that this coexistence in the ISM band can degrade the performance of the WSNs. The wide deployments, large transmit power, and large coverage range of IEEE 802.11 devices and other proprietary devices can degrade the performance of WSNs significantly when operating in overlapping frequency bands. The coexistence of wireless personal area networks (WPAN) with other wireless devices operating in an unlicensed frequency band is addressed in reference [1].

WSN devices are not only a victim but are also an interferer sometimes [2]. The coexistence interference can be avoided by the intelligent use of three types of diversity, namely frequency, time and space. Coexistence issues in unlicensed bands have been the subject of extensive research. Some solutions are also suggested in references [3,4].

Researchers and industry are working to improve the performance of WSNs in terms of cost, energy consumption, data rate, robustness, networks throughput, QoS and security, etc. Considerable hardware and software enhancement has been implemented in recent years to enhance the network performance. A range of logical techniques have been employed to achieve the required network performance, such as power aware MAC, cross-layer design technique, efficient sensing technique, and significant enhancement in hardware design, etc., but these techniques have their own limitations.

II. APPLICATIONS

2.1 Military applications

Military applications are very closely related to the concept of wireless sensor networks. In fact, it is very difficult to say for sure whether motes were developed because of military and air defense needs or whether they were invented independently and were subsequently applied to army services. Regarding military applications, the area of interest extents from information collection, generally, to enemy tracking, battlefield surveillance or target classification [5][6]. In addition, some military applications require a large bandwidth, minimum channel access and communication delays. For such applications, CR-WSNs can be a better option.

2.2 Applications to robotics

Many applications coupling motes and robots have been proposed. For example, Robo mote is a tiny robot developed by the USC Center for Robotics and Embedded Systems to promote research in large-scale sensor network where robots participate [7]. Applications already implemented [8] are the detection of level sets of scalar fields (like isothermal or isobar curves) using mobile sensor networks and imitation of the function of bacteria for seeking and discovering dissipative, gradient sources[9]. The objective was the tracking of a light source with simplified algorithms. In addition, a solution to the “coverage problem” by robots and motes is proposed in[10].

2.3 Environmental Applications

Another important area of wireless sensor networks are environmental applications which includes large-scale earth monitoring and planetary exploration; chemical/biological detection; precision agriculture; biological, earth, and environmental monitoring in marine, soil, and atmospheric contexts; forest fire detection; meteorological or geophysical research; flood detection; bio-complexity mapping of the environment; and pollution study.

2.4 Medical Application

Wireless sensor network research is being performed to address medical applications. In particular, a common vision found in the research arena is to provide sensing and wireless communication for assisted living facilities to improve lifestyle, to improve health care, and to support long term medical studies. Our research work is solving WSN problems for real-time response, data association, reliability and dependability, security and privacy, and analysis via programs that determine circadian rhythms. The work is taking an end-to-end view from collecting the data (via dust-like motes) to its analysis and use by doctors. As part of this research we are building (and have partly constructed) a WSN-based medical test bed.

2.5 Home applications

Many potential and emerging indoor applications require a dense WSNs environment to achieve an adequate QoS. Conventional WSNs experience significant challenges in achieving reliable communication because ISM bands in indoor areas are extremely crowded [11]. Some examples of the indoor applications of WSNs are intelligent buildings, home monitoring systems, factory automation, personal entertainment, etc. CR-WSNs can mitigate the challenges faced by conventional indoor WSNs applications.

III. Research Trends and Open Research Issues

Although a number of papers have been published in this area, still many research issues remain to be addressed. Less than 15 papers were published in IEEE journals in 2011 and 2012. No clear standard exists and there have been several unclear proposals. Many areas need to be explored, such as low computational and energy efficient spectrum sensing, spectrum management, clustering, energy consumption, spectrum handoff, channel allocation, channel access, geo-location information sharing, self-topology generation, cross-layer optimization of protocol stacks, etc. In addition, many issues remain to be resolved, such as coexistence with other CR systems, legal issues to access incumbent channels, limit of interference with PUs, transmission power control etc

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