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Cognitive Radio Sensor Network Future of Wireless Sensor Network

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Abstract: Need of wireless sensor network (WSN) is increasing in various application areas. Resource restricted Traditional WSN is not able to satisfy this increase in demands. Many WSN is using unlicensed band (ISM band) so this band become overcrowded. Cognitive radio in WSN with opportunistic behavior and dynamic spectrum access can satisfy increasing demands and utilized spectrum bands effectively and efficiently. In this paper detail study of Cognitive Radio Sensor Network (CRSN) with architecture, hardware structure and challenges are explored.

Keywords: Cognitive radio, dynamic spectrum access, spectrum sensing.

I. INTRODUCTION

In this advance era communication network becomes an essential thing of human life employed in areas of healthcare, social networking, security, surveillance and geo-informatics. A wireless sensor network (WSN) having large number of sensor nodes, to sense e.g. temperature, humidity, vehicular movement, lighting conditions, pressure, the presence or absence of certain kinds of objects and so on in the vicinity. In field of investigation the sensor nodes are deployed as WSN can be operated in both licensed and unlicensed band.

Currently WSN working in unlicensed band also called as ISM (industrial scientific medical) band i.e. 2.4 GHz. Many wireless technology e.g. Bluetooth, and Wi-Fi using same ISM band, So that this band becomes overcrowded which ultimately results in degrading performance of each other technology.

Traditional WSNs in licensed band used only by licensed user i.e. primary user (PU). Due to fixed spectrum access when PU is not using allocated frequency spectrum then spectrum under utilization taking place which increase need of new spectrum allocation policy. Cognitive radio with opportunistic behaviour and dynamic spectrum access came in existence to solve this problem. Cognitive radio built on a software-defined radio, is defined as an intelligent wireless communication system that is aware of its environment communicated reliably with efficiently utilize the frequency spectrum. Here we discussing new WSN technology with Cognitive radio called as Cognitive Radio Sensor Network (CRSN).

CRSN can be defined as a distributed network of wireless cognitive radio sensor nodes. It senses an event signal and collaboratively communicates their readings dynamically over available spectrum bands in a multi-hop manner. CRSN is best suited for the application-specific requirements. Cognitive radio sensing the spectrum and find out available vacant bands. Afterwards dynamically changing operating parameters over transmission, Cognitive radio can get access of vacant band. This process being repeated itself so therefore it's called as cognitive cycle.

The content of the paper is organized as follows. In section II, we present architecture of CRSN with possible topologies. Dynamic spectrum management is defined in section III and section IV explored different application areas of CRSN. Challenges for practical implementation of CRSN are discussed in section V. Finally conclusion states in section VI.

II. CRSN ARCHITECTURE

CRSN is the next generation sensor network paradigm. A typical architecture of CRSN is showing in fig.1.communication of CRSN is taking place in following ways sensor nodes sensing environment as well as spectrum and send information to next hope in an opportunistic manner. Sink is connected to this hope so ultimately this information is receiving by sink. The sink may be equipped with cognitive radio capability which can perform spectrum decision. CRSN may have different topologies due to application dependent nature. This different topology shown in fig.2

Clustered topology-this topology shown in fig.2 a) best suited for effective spectrum management. There is need of design a common channel to exchange various control data, such as spectrum sensing results, spectrum allocation data, and neighbor discovery and maintenance information. Sensor nodes have a leader for a group called as cluster head which may perform operation of spectrum sensing and local spectrum bargaining.

Heterogeneous and Hierarchical CRSN-this type of topology shown in fig.2 b) consisting of an extra node called as actor node. Actor node equipped with more power so it can be works as relay node due to longer transmission range. This actor node with WSN forms a heterogeneous and multi-layer hierarchical topology.

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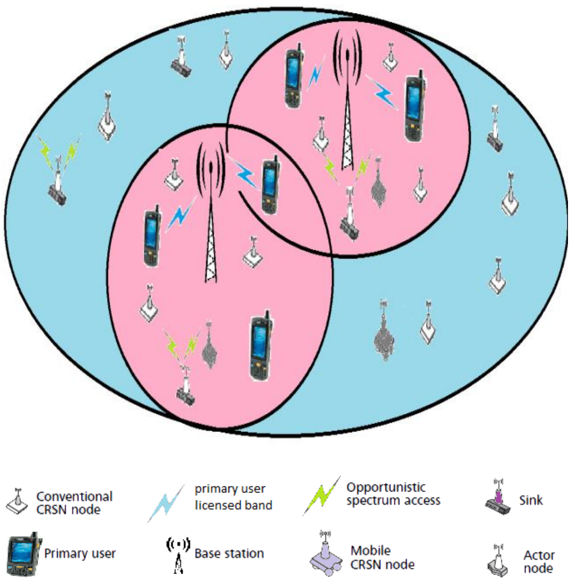
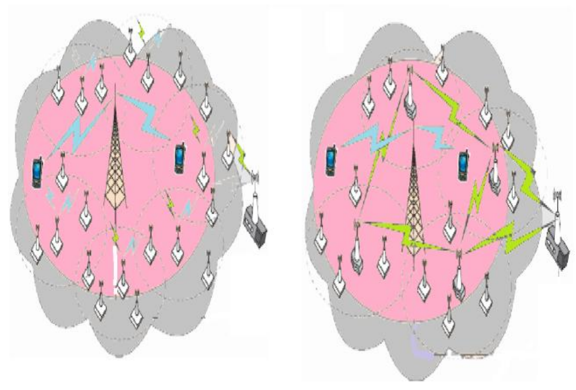


Figure 1 Cognitive Radio Sensor Network(CRSN)

Ad Hoc CRSN-this one is infrastructure less topology. The communication between sensor nodes and sink is taking place in multi hop Ad Hoc manner. Advantage of Ad Hoc is less communication overhead. Spectrum sensing can be performing individually or coordinately by sensors.



a) b)

Figure 2 different types of topologies a) Clustered CRSN; b) Heterogeneous hierarchical CRSN.

III. DYNAMIC SPECTRUM MANAGEMENT

Dynamic spectrum management is fundamental functionality of CRSN for develop adaptive allocation policies to effective and efficient use of frequency spectrum which perform by following steps.

Spectrum sensing-spectrum sensing can be defined as operates sensor nodes in an opportunistic manner to collect information of PU for transmission. This functionality makes CRSN differ from traditional WSN. This special operation needs extra power consumption so we need to select application specific model. Various spectrum sensing methods are shown below in table 1 with its advantages and disadvantage. Figure 1 Cognitive radio sensor network (CRSN) architecture, Figure 2 a) possible network topologies for clustered CRSN; b) a heterogeneous hierarchical CRSN.

Spectrum decision-spectrum decision sets parameters for communication on the basis of prior channel state information decision about the channel and transmission parameters (i.e. transmission power, modulation) is taking place by analyzing sensing data of CRSN nodes.

In this operation due to inherent resource constraints characteristics of CRSN violates because of transmission power having second priority and processing capability, amount of extra packets is mostly ignored.

Spectrum Handoff-Spectrum Handoff is the fundamental functionality of cognitive radio defined as, When a PU starts using a previously available channel, and CRSN node must detect this activity within a certain time through spectrum sensing methods. Then they immediately move to another available channel decided on by an effective spectrum decision mechanism, even if they have ongoing transmissions. Nodes may also want to switch channels if channel conditions get worse, with reducing communication performance.

Table 1 Overview of Spectrum Sensing Methods.

Spectrum sensing Method	Disadvantages	Advantages
Matched filter	Requires a priori info on PU transmissions, and extra hardware on nodes for synchronization with PUs.	Best in Gaussian noise. Needs shorter sensing duration (less power consumption).
Energy detection	Requires longer sensing duration (high power consumption). Accuracy highly depends on noise level variations.	Requires the least amount of computational power on nodes.
Feature detection	Requires a priori knowledge about PU transmissions. Requires high computational capability on nodes.	Most resilient to variation in noise levels.
Interference Temperature	Requires knowledge of location PU and imposes polynomial calculations based on these locations.	Recommended by FCC. Guarantees a predetermined interference to PU is not exceeded.

Spectrum Handoff is done in two steps, first an alternate channel must be determine, then a receiver-transmitter handshake must be performed on the new channel. Only after that nodes may continue their transmissions. All of these additional operations incur long delays and hence buffer overflows taking place, which lead to packet losses, degradation in reliability, and ultimately resource waste in CRSNs.

In a central spectrum allocation scheme that tries to minimize spectrum handoff has been proposed for CRSNs. However, none of the previous studies on spectrum handoff consider the challenges posed by the inherent limitations of CRSNs. As an open research issue, minimizing the effect of spectrum handoff on various communication layers must be analyzed for CRSNs. At

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the same time, the development of central and distributed spectrum handoff solutions for CRSNs must be investigated.

IV. COGNITIVE RADIO HARDWARE STRUCTURE

Hardware structure of cognitive radio-based sensor network is typically composed of the power unit, sensing unit, processing unit, the cognitive radio platform and the RF unit. This is shown in figure 3.

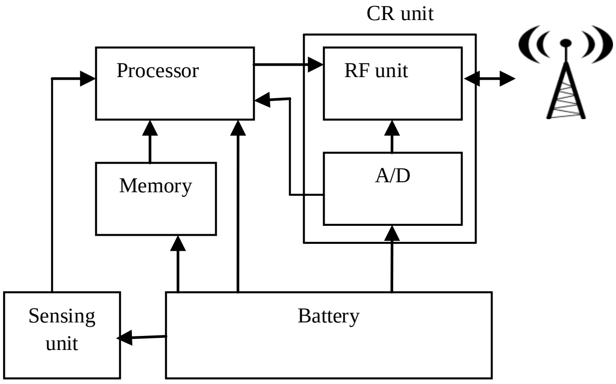

Figure 3 Hardware Structure of a Cognitive Radio Sensor node.

Two new unit i.e. location finding unit and mobilize unit are required for application specific network. There is an extra unit in Cognitive radio sensor network related to traditional wireless sensor node which is the RF unit of the cognitive radio sensor nodes. The cognitive engine is responsible for cognitive cycle which enables CR sensor nodes to dynamically adapt their communication parameters is done by even though this hardware architecture looking promising in terms of dynamic spectrum access for sensor nodes, there are noticeable challenges posed to a resource-constrained wireless sensor networks. Wireless sensor networks are constrained by resources such as power, low complexity processing device, communication and memory. As a result of these limitations, the cognitive radio capability is also affected.
For instance, to increase the network lifetime there should be necessary to consider low energy consumption spectrum sensing design and energy saving protocols. For better system architecture for CRWSN, there should be adaptive, dynamic MAC protocol using reinforcement learning technique. Also, there should be cross-layer energy management protocol integrating the physical and the MAC layer.

V. CHALLENGES WITH CRSN

With spectrum handoff capability, tactical surveillance CRSNs may be less susceptible to interception and jamming threats.still CRSN having limitation as follows.

- Node Development: For realization, development of efficient and practical cognitive radio-based sensor network is one of the major issues for in CRWSN. Considering the design principles and operation objective of the sensor network, the limitations of the nodes, hardware and software requirements for sensor nodes with cognitive radio capabilities, there is the need for extensive study in order to come up with such efficient and practical nodes.
- Node Deployment: There is the need for proper mathematical analysis for optimum node deployment for various topologies for the purpose of developing efficient and practical node deployment mechanisms. Where there exists information about the primary user activities, spectrum characteristics may provide improvement of the network lifetime and transmission quality.
- Optimal Network Coverage: As a result of the primary user activity couple with node failure, the spatial location of sensor nodes may vary. Under this condition, to maintain maximum network coverage, it is certain some nodes may have to transmit with more power, which results in power and energy consumption. But on the other hand, connectivity may be achieved at longer ranges with lower frequencies which help to save transmission energy. It then becomes necessary to consider dynamic spectrum management while analyzing optimum network coverage. Also a new topology schemes which addresses tradeoff between network lifetime and network coverage should be introduced.
- Coordinated and Uncoordinated Operation: Operations such as spectrum sensing, spectrum detection, spectrum allocation, spectrum sharing, and spectrum handoff may be performed individually by sensor nodes or cooperatively among sensor nodes. It therefore becomes necessary to carry out detailed comparison between the coordinated and uncoordinated network operation for efficient communication in a resource-constrained CRSN.
- Clustering Issue: For a cluster-based CRWSN, clustering and hierarchy formation increases communication overhead which may be increased due to node mobility and spectrum handoff. Therefore, for applications using cluster-based and hierarchical topologies, dynamic spectrum aware cluster formation and maintenance techniques must be investigated.

VI. CONCLUSIONS

Cognitive radio can improve spectrum utilization and communication quality with opportunistic spectrum access capability and adaptability to the channel conditions. Dynamic spectrum management provides multiple channel access which helps to solve the problems caused by the dense deployment and bursty communication nature of sensor networks. Even though cognitive radio could have lots of advantage like dynamic spectrum access, adaptability it comes with shortcoming. There exist significant challenges for the realization of CRSN. If we able to solve this challenges then CRSN will become a new future paradigm for the next generation wireless sensor network. There are lots of prospect and potentials attributable to this new research area in sensor networks.

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