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Energy Efficient Architecture to Cognitive Radio Wireless Sensor Networks

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Abstract— **Cognitive radio has been considered as a key technology for future wireless communications and mobile computing. In this cognitive radio technology spectrum play an important role. Effective utilization of frequency spectrum improves the quality of the communication. In this paper we attempt to improve the radio spectrum utilization by proposing cognitive radio based wireless sensor networks. Network architecture of a sensor network plays a key factor in improving the efficiency in cognitive radio environment. Specifically we propose new spectrum aware network architecture. This paper includes also the novel hierarchical protocols along with heterogeneous and fault tolerant architecture for data dissemination networks.**

Keywords- Cognitive; Wireless sensor networks; Hierarchical protocols; Heterogeneous networks.

I. INTRODUCTION

The research area of wireless sensor networks is an advancing technology which has opened new research issues. Its number of applications in various sectors of military and civilian applications has created demand for the design of more efficient and effective wireless sensor networks. The wireless sensor network comprises of number of sensor nodes which are equipped with a radio transceiver. The wireless sensor nodes are constrained in energy supply, computational memory space, speed and bandwidth. In spite of limitations sensor nodes can reliably and accurately report the surrounding environmental changes. These features are exploited in association with cognitive radio for improving utilization of radio spectrum.

A ''Cognitive Radio'' is a radio that can change its transmitter parameters based on interaction with the environment in which it operates [1].

The cognitive radio transceiver consists of the radio front-end and the baseband processing unit. The RF technology observes the spectrum and indicates the spectrum holes. In cognitive radio there is a co-existence of licensed and unlicensed wireless users in a common area. There are special measures taken so that the usage of licensed user is not interrupted. To improve spectrum utilization by facilitating spectrum sensing in the concept of "cognitive radio based wireless sensor" has been introduced. In a cognitive system the sensing of the spectrum is also done by the sensor networks and forwarded to the base stations. Further the collected information is processed and sent to another network where further spectrum utilization takes place. The entire process is carried out without interfering with the licensed users.

This paper is organized as followings: In section II we are introducing our energy efficient architecture, in section III we are discussing about the hierarchical protocols based architecture for data dissemination network, in the Section IV we brief description about the heterogeneous and fault tolerant architecture, section V concludes this paper.

II. SPECTRUM AWARE NETWORK ARCHTECTURE

The architecture of the cognitive wireless sensor network consists of individual networks working together. Each network is interconnected. The role of sensor network is described in detail.

A. Wireless sensor network model:

To improve the utilization of radio spectrum we introduce cognitive wireless sensor network based network architecture. This architecture contributes to the effectiveness of sensor networks in a cognitive environment. It manages the coexistence of unlicensed spectrum users and licensed spectrum users. In our research we intend to create two distinguish networks:

One of the networks is for the purpose of sensing the availability of the spectrum.

The other network is for the purpose of processing and communicating the sensed data to the operational networks.
The initial sensing network is known as Sensing sensor network. It consists of sensor nodes arranged in a particular manner to increase the life time of the network. The backbone network is known as Data Transmitting network. This network is responsible for data distribution to the operational networks.

By this distinction we are minimizing the load on the sensors in the secondary network i.e. processing, analyzing and distributing the sensed data on the same front. This

multitasking results in battery drain and decreasing the life time of the network. We have divided the tasks as a result we have improved network spectrum efficiency. And by distinguishing the secondary network we have achieved increase in the life time of the network. Therefore we have created sub networks based on these functionalities as shown in the Fig.1.

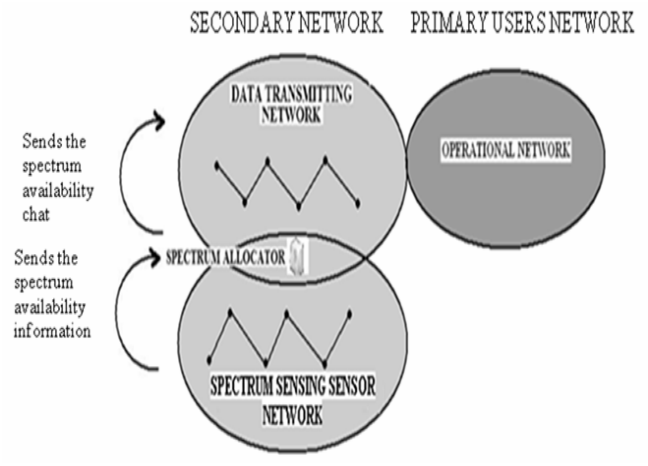

Figure 1. Proposed network architecture of cognitive wireless sensor network

The data transmitting network is associated with the operational network of unlicensed users. The sensor nodes are designed in such a manner that the data sensing is made effective and efficient. The sensors are placed in a grid paradigm for exploiting the characteristics of a sensor grid. The grid structure provides a seamless access to the network resources in a pervasive manner.

The sensed spectrum data is collected by one or more base stations and forwarded to the central head called spectrum allocator. In spectrum allocator the spectrum vacancy chart is dynamically formed based on the collected data. This corresponding data is distributed to the operational networks in the secondary network. This forwarded information shows the availability of the spectrum. It is used by the unlicensed users and disturbances to the licensed users are avoided [6].

B. Integrated Circuitry model:

We also suggest an innovative approach of using integrated circuitry with cognitive wireless sensor network. In this model the spectrum vacancy is sensed by the wireless sensor network (same as the above model). And the collected information is supplied to the embedded system. This implementation of VLSI technology will give us independence to modify the network architecture with respect to the future requirements and demands.

Sending the sensor sensed information to the higher levels is also a challenging part of the entire process. We intend to create a Virtual Private Network (VPN) over the internet and a secured channel is established. We also created a gateway for translating requests and upload/downloading information remotely. This will increase the accessibility to the wireless sensors. With increased level of interactions with the sensors we developed ease of operation and maintenance. To increase the life span of our sensor network we are using passive source of energies. Fig.2 gives the functional block diagram of VLSI implemented on cognitive wireless network.

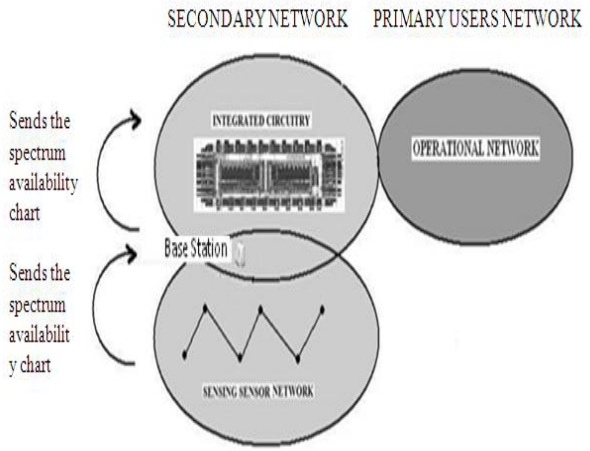

Figure 2. VLSI implemented on cognitive wireless network

III. HIERARCHY PROTOCOL BASED ARCHTECTURE

The key idea of Hierarchical protocols is to consume energy efficiently by means of forming sensor nodes as clusters, levels or sectors. In this paper we are proposing non-uniform leveling and sectoring based architecture for energy efficient protocols.

A. Non-uniform levelling:

In [2] authors proposed a level controlled clustering based routing algorithm in which total sensor field is divided into levels (with uniform distance between levels). By using various power levels at the base station, the sensor field is hierarchically partitioned into levels of increasing radius. Levelling divides the network into logical zones based on proximity from base station, where by the packet is transmitted from node in higher zone (level) to a zone with lesser depth.

Each packet should pass through nodes near base station to reach base station. Because of this, nodes near base station drain out of power very fast. For efficient energy consumption at nodes near base station we are proposing non-uniform levelling. In this method sensor field is divided into non-uniform levels (with non-uniform distance between levels). Sensor field near base station is divided into levels with higher separation distance and field far from base station is divided into levels with lower separation distance as shown in fig. 3.

To ensure propagation of packets from one level to another, separation of levels should satisfy following equation

$$p_r \geq D_n + D_{n-1} + \varepsilon \quad (1)$$

Where P_r be the propagation range of each sensor node and D_n and D_{n-1} be the separation of two successive levels as shown in fig. 4 and ε is a small value.

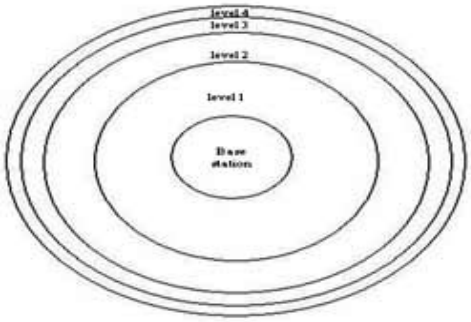

Figure 3. Non-uniform levels

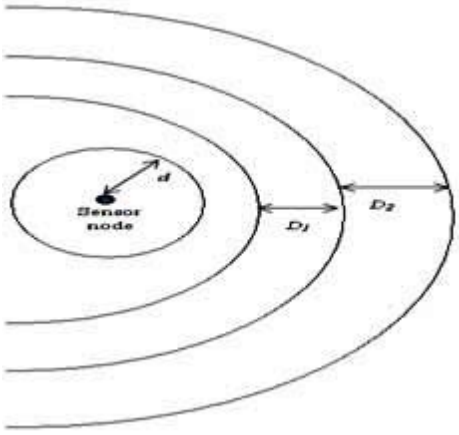

Figure 4. Sensor node range of propagation and level separations

B. Non-Uniform Sectorization

In PASCAL [3] authors have proposed an information-driven architecture for routing in Wireless Sensor Networks. The key idea was to hierarchically partition the sensor field into uniform levels and uniform sectors of increasing angular measure. In this algorithm packets are forwarded by only nodes in adjacent sectors and lower level. Using PASCAL algorithm authors have shown that energy of sensor nodes are consumed efficiently.

In particular applications like accident monitoring systems it is well known that near turning accident occurs more. In such scenarios nodes near turnings drain out of power easily due to more traffic load. Placing more angular spacing between sectors at these particular places reduce energy consumption. Non-uniform levelling and Sectorization is shows in fig. 5.

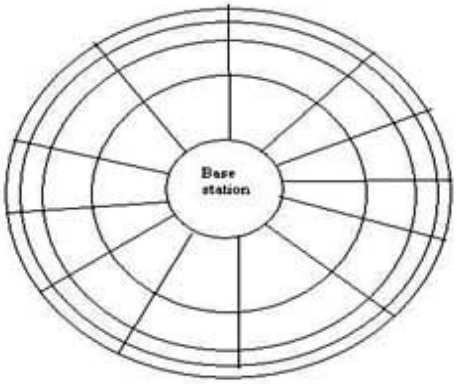

Figure 5. Non-uniform sectors

To ensure propagation of packets, angular separation and level separation distance should satisfy following equation

$$p_r \geq \sqrt{\left(D_n + D_{n-1}\right)^2 + D^2\left(\tan\theta_1 + \tan\theta_2\right)^2} \quad (2)$$

$$D = D_{n-2} + d$$

Where d is distance of level $n-2$ to base station , D_n, D_{n-1}, D_{n-2} are distance between levels as show in fig. 6, p_r is propagation range of a sensor node , θ_1 and θ_2 are angular spacing between sectors and ε is a constant.

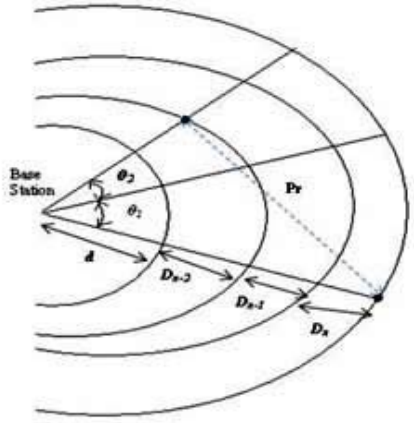

Figure 6. Sector spacing and level spacing

C. *Hybrid protocols*

In data centric protocols [4] base station advertises its query into total sensor field and waits for the data from sensor nodes. Each query have certain attributes, nodes which have data that matches with these attributes will only respond to the query and starts sending their data to base station. As nodes with required data are only sending data energy of sensor field is utilized efficiently. Taking advantage of data centric protocols on hierarchically partitioned (non-uniform levels and non-uniform sectorizied) networks reduces unwanted power consumption in sensor field.

IV. HIERARCHY PROTOCOL BASED ARCHTECTURE

A Heterogeneous network is a wireless network with different technologies. The heterogeneous wireless sensor network consists of sensor nodes with different computing power and sensing ranges. These heterogeneous networks are more flexible and fault tolerant. The presence of heterogeneous nodes (i.e., nodes with an enhanced energy capacity or communication capability) in a sensor network is known to increase network reliability and lifetime. It is the optimal mixture of many inexpensive devices and high capability devices that can extend the (life time) duration of the networks performance.

In a multi hop sensor network with many-to-one delivery the nodes nearer to the sink expend more energy. In some cases there are chances of node failure in wireless sensor network. Particularly in the cases where the levelling and sectoring techniques are implemented, failure of the node in the level nearer to the base station could lead to network disruption. To avoid such scenario we shall deploy sensor nodes which have higher capabilities such as larger battery power and greater communication range in the level nearer to the base station. Whereas in the outer levels we can use lower ability devices as shown in Fig. 7 and Fig. 8.

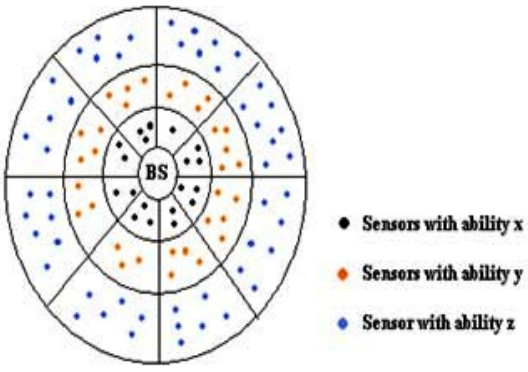

Figure 7. Heterogeneous WSN

In a distributed sensor network there are a set of sensor nodes, a set of processing elements (PE) and communication network. This communication network interconnects various PE's. Each processing element is associated with one or more sensors. Data is transferred from a sensor to its associated processing element. The data integration takes place in this processing element. The entire collection of processing element coordinates with each other to achieve better estimation of the environment and delivering the data to the base station. The LEACH protocol is a protocol for forming clusters in a self-organized homogeneous sensor network where the sensors are located far from the base stations. In LEACH protocol some nodes are elected as cluster-heads. The other nodes communicate to the nearest cluster-head. This protocol randomly rotates the job of cluster-head based on the node's remaining energy. This uniformly distributes the energy consumption throughout the network [5].

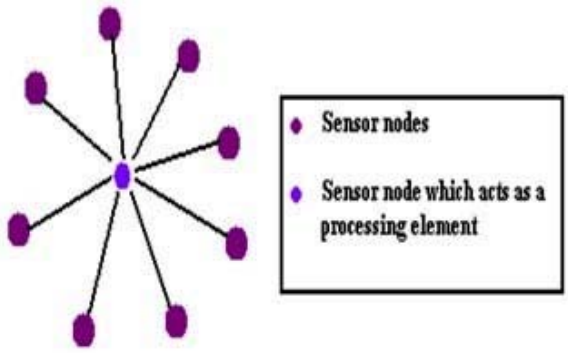

Figure 8. Sensor network

In another scenario we consider MICRO SERVERS incorporated in the wireless sensor network for the purpose of monitoring energy levels. We shall consider a pyramid structured network of sensors, micro servers and the base station. The sensors are in the lower level monitoring surrounding environment. The micro servers are in the level above providing connectivity between the sensors and the base station. The base station is on the top of the pyramid. Concurrently partitioning the sensors into clusters and assigning with individual micro-servers as cluster head will maximize the monitoring lifetime of the layered WSN. The leveled wireless sensor networks can be seen in the fig. 9 and fig. 10.

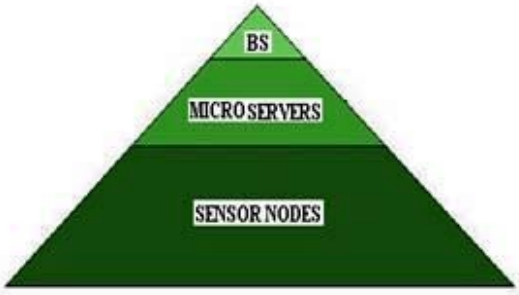

Figure 9. Pyramid structured WSN

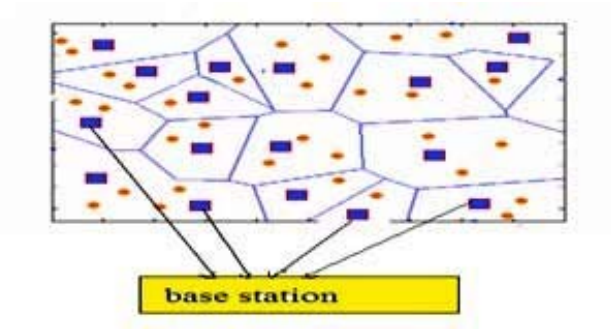

Figure 10. Clustered network in WSN

The data sensed by the sensor nodes will communicate with the micro server. The micro server will process the data and forwards the information to the base station. With the use of micro server we will be getting rid of redundancy and only necessary information will be sent to the base station. This will result in effective utilization of energy. Using this structured network we can increase the life time of the WSN. There is continuous monitoring of the network by the micro severs. These micro servers can identify the failure of sensor nodes in the network and will immediately update the base station about the failure. Usually in a sensor network the monitoring of the network is done by the base station. The base station will periodically flood the network to identify the network status. This traditional method results in wastage of the recourses. Whereas by using these micro servers the base station will be periodically updated about the clusters (group of sensors) in which the micro servers are placed.

CONCLUSIONS

New research issues arise as the concept of wireless sensor network based on cognitive radio is introduced. In our research we have propose few innovative and energy efficient new techniques of using wireless sensor network in cognitive environment. For effictive utilization of cognitive radio spectrum improves the lifetime of the sensor network also.

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