A REVIEW ON COGNITIVE RADIO WIRELESS SENSOR NETWORKS

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Abstract: A wireless sensor network consists of wireless sensor nodes with in-build communication capabilities, but with limited battery. Wireless sensor networks (WSNs) are networks of randomly distributed autonomous devices that can sense the physical conditions of any system cooperatively and then produces electrical output which can be further processed for any desired operation. But due to the swift proliferation of the various wireless communication techniques the frequency bands used for wireless communication almost depleted. In order to cope up with this scarcity of frequency spectrum, cognitive radio comes to the rescue. Cognitive radio is a solution to the limited frequency spectrum which allows the secondary (unlicensed) users to utilize the frequency spectrum of the primary (licensed) users, when they are not using their licensed spectrum. A cognitive wireless sensor network is a most recent and promising technique for utilizing our useful and limited spectrum very intelligently to increase the spectral efficiency.

Indexterms- CRWSN: Cognitive radio wireless sensor networks, PU: Primary user, SU: Secondary user, Licensed Spectrum, Clustering

I. INTRODUCTION

Wireless sensor networks have evolved as an important technology in the era of wireless communications. Wireless sensor networks are the networks consisting of a large number of tiny sensors densely deployed in a particular area of application, which can cooperatively communicate with each other. Each and every sensor in WSN consists of processing unit, sensing unit, memory unit, power unit and communication unit as shown in Fig.1 **[1]**.

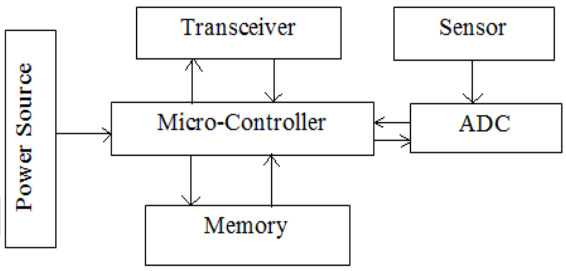

Fig. 1: Components of sensor node in WSNs

According to the particular application the position of sensors can be pre-determined or random. In case of random deployment of sensor nodes, the sensing protocols and algorithms must possess self-organizing properties.

II. COGNITION IN WIRELESS SENSOR NETWORKS: COGNITIVE RADIO WIRELESS SENSOR NETWORKS

Due to the swift proliferation of the various wireless communication techniques the frequency bands used for wireless communication almost depleted. In order to cope up with this scarcity of frequency spectrum, a term cognitive radio was first coined by J. Mitola. “Cognition” refers to the process of acquiring knowledge and performing through senses, experience and the available information from the particular system’s environment. When nodes with cognitive capabilities are introduced into an entire network of communicating sensor nodes, it gives rise to exciting new opportunities in sensor network research that could overcome the limitations imposed by current design techniques **[2].** Cognitive radio is a solution to the limited frequency spectrum which allows the secondary (unlicensed) users to utilize the frequency spectrum of the primary (licensed) users, when they are not using their licensed spectrum **[3]**. A cognitive wireless sensor network is a most recent and promising technique for utilizing our useful and limited spectrum very intelligently to increase the spectral efficiency **[4]**.

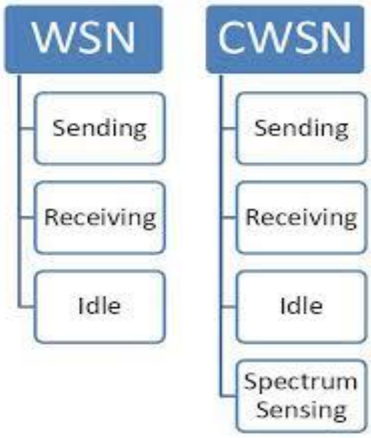

Fig. 2: Wireless Sensor Network (WSN) Vs. Cognitive Wireless Sensor Network (CWSN)

Cognitive wireless sensor networks are more efficient than the conventional wireless sensor network in terms of extending lifetime of the wireless sensor nodes **[5]**. Similar to the existing WSNs, a CWSN consists of many cheap tiny sensors, operating on limited battery energy. In a WSN, each node has operates in only three states that are sending, receiving or in idle state. However, in a CWSN, despite from these operating states there is another state called sensing state where the sensor nodes intelligently sense the spectrum of primary users to find spectrum opportunities. Fig. 2 depicts different states for both WSN and CWSNs.

III. LITERATURE REVIEW

Han et al. [6] discussed that in the designing of CRWSN both energy efficiency and the inference free environment for PU are considered the important factors. But due to CR functionality in CRWSN the network lifetime becomes shorter and shorter. To cope up with these issues an energy efficient channel management scheme is proposed in this paper. This approach helps to maximize the energy efficiency with less interference to the PU.
Mustapha et al. [7] discussed a cluster based energy-efficient cooperative spectrum sensing for cognitive radio wireless sensor networks (CRWSN) To spectrum sensing should also be energy efficient so that it consumes less energy and thus increases the lifetime of CRWSNs. In this paper an energy-aware clustering (EAC) is proposed to increase the network lifetime. EAC algorithm has three phases for its operation: the initialization phase, the set-up phase and the coordination phase.
Zahmati et al. [8] discussed that in cognitive radio opportunistic spectrum access is there to access the limited spectrum in a useful way but in CRWSN the opportunistic spectrum should also be energy aware because the sensor nodes in CRWSN are battery powered and have very limited power. Keeping both these requirements that in mind an energy aware secondary user selection in CRWSN is presented in this paper. In this approach firstly the certain optimal number of secondary users is identified on the basis of requirement of given application. Secondly, the most eligible candidates out of these secondary users are selected on the basis of their respective probability.
Liu et al. [9] proposed an Ant Colony optimization based Energy efficient sensor scheduling problem algorithm (ACO-ESSP) in cognitive radio wireless sensor networks employing the heterogeneous sensors. However, the topology and the infrastructure of the sensor nosed is not discussed in this paper. The heterogeneous sensor nodes employed in this network are battery powered and they have very limited energy supply. The algorithm proposed in this paper has helped to improve the overall system throughput of the secondary network along with the primary user network. Instead of improving the network lifetime, the objective of this paper is only to maximize the system throughput.
Ren et al. [10] formulated a scheme named dynamic channel access to improve energy efficiency in CRWSNs. The dynamic channel access is discussed in this paper to improve the energy efficiency in the clustered CRWSN. Also in this scheme the energy consumption during the sensing as well as switching are taken in account of overall energy consumption. Moreover in this paper two schemes named channel sensing and channel accessing are proposed to improve the inter-cluster as well as intra-cluster data transmissions which will in turn improve the energy efficiency.
Ozger et al. [11] proposed mobility aware event to sink spectrum aware clustering (mESAC) protocol for the efficient communication in CRWSN. In this paper it is discussed that the CRWSNs are event driven system i.e., when any event occurs in CRWSN, it is sensed by the sensor nodes and then this information is collectively transmitted via the vacant channels to the sink node in the multi-hop fashion. The main reason for the better performance of mESAC is that the nodes that have highest number of vacant channels in its neighborhood is selected as a cluster head. Also in this approach, maximum event frequency is achieved which again increases the energy efficiency.
Usman et al. [12] proposed an energy-efficient network infrastructure consisting of ad hoc i.e., mobile cognitive radios and infrastructure i.e., static wireless sensor nodes. The Ad Hoc cognitive radios (CR) act as cluster heads and the static wireless sensor nodes which are in the communication range of one CR act as participants of one cluster. Also in this paper cluster updating and subset formation (CUSF) process is proposed to regularly update the clusters and about the active subset and the no of subsets in one cluster according to the movement of CR.
Wu et al. [13] discussed cluster based energy-efficient collaborative spectrum sensing for CRWSN. As in the military and civil applications high energy efficiency is required, it is a promising technique which is able in doing so. In this scheme centralized

CRWSN is proposed in which there are one secondary sink node (SN) and N cognitive sensor (CS) nodes. This technique is formulated to increase the energy efficiency of CRWSN under various constraints like the false alarm probability and the collision events.

Kim et al. [14] presented a novel cognitively inspired artificial bee colony clustering (ABCC) algorithm for reducing the energy consumption of CRWSN. This clustering technique is better than LEACH and HEED (hybrid energy efficient distributed) in a way that it determines the optimal number of cluster heads in a network at each stage. But in LEACH and HEED protocol have a limitation that there is not any information about this fact at any stage. In ABCC algorithm, the cluster heads and the participants of these clusters are selected on the basis of a binary value assigned to each node.

Samir et al. [15] proposed the different cluster structures in cognitive radio wireless sensor networks (CRWSN) which are modified single hop cluster structure, multi-hop cluster structure and hybrid cluster structure. Also in this paper enhancement to the single-hop structure is done by restricting the number of registered nodes to the cluster head to only three. This enhancement resulted in the slight decrease in the energy consumption as compared to the unmodified single-hop cluster structure. This enhancement resulted in the slight decrease in the energy consumption as compared to the unmodified single-hop cluster structure. According to the MATLAB simulations, the multi-hop has got the first rank in terms of highest energy consumption but with an advantage of covering a large coverage area. Also the hybrid cluster structure outperforms both the single-hop and multi-hop cluster structures in terms of minimum end to end delay between the nodes.

Table 1: Inferences Drawn From Literature Review

S. No.	Reference	Approach	Description
1.	**[6]**	Energy-Efficient Channel Management Scheme	• Energy efficiency is maximized with less interference to PU. • The proposed scheme determines the channel's operation mode even in presence of noise.
2	**[7]**	Energy-aware cluster based cooperative spectrum sensing	• Cooperative spectrum sensing is there. • Spectrum sensing energy consumption, intra-cluster and inter-cluster energy consumption are taken into account. • Then optimal number of clusters for the network is determined.
3	**[8]**	Energy-aware secondary user selection	• Two benchmarks are proposed • First is sensing accuracy benchmark and second is energy benchmark. • Network's performance is analyzed by taking one benchmark into account at a time. • Results show that there is trade-off between sensing accuracy and network lifetime is there.
4.	**[9]**	Energy-efficient sensor scheduling algorithm employing heterogeneous nodes	• It improves the secondary network's throughput. • It employs heterogeneous nodes in CRWSN.
5.	**[10]**	Dynamic channel access to improve energy efficiency	• Channel sensing scheme is proposed for intra-cluster data transmission. • Channel accessing scheme is proposed for inter-cluster data transmission. • Future scope is also discussed for rechargeable batteries.
6.	**[11]**	Event to sink spectrum aware clustering	• In first phase intermediate nodes between event position and sink are recognized • In second phase clusters are formed. • Re-clustering probability is investigated and our approach decreases this probability.
7.	**[12]**	Energy-efficient infrastructure sensor network	• Divides the cluster into subsets. • Elects nodes for actual sensing in subset. • Switching the active subset to sleep mode by scheduling.
8.	**[13]**	Cluster-based energy-efficient collaborative spectrum sensing	• The energy efficiency is maximized under the collision constraint and false alarm probability constraint. • The problem of finding optical threshold level is converted to searching optimal received SNR by the FCS. • Results show that Energy is maximized for a unique time

			fraction.
9.	**[14]**	Cognitively inspired artificial bee colony clustering algorithm	• Exact behavior like the swarm of bees. • It employs fewer control parameters. • It outperforms various other protocols. • It is superior to other approaches as the number of nodes in network increases.
10.	**[15]**	Modified single-hop cluster structure, multi-hop cluster structure and hybrid cluster structure	• Multi-hop has highest energy consumption. • Hybrid cluster structure has min. end to end delay.

IV. CONCLUSION

Some problems faced by the conventional wireless sensor networks have been eliminated by the entrance of cognitive radio wireless sensor networks, but extending the lifetime of the network is still a major challenge. In this paper, techniques for increasing the lifetime and energy efficiency and for decreasing the end to end delay have been reviewed. But, there are still a number of open research areas for developing a routing protocols and clustering techniques to further improve the energy efficiency and thus the lifetime of the network.

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REFERENCES

[1] Tripathi A, Gupta HP, Dutta T, et al. Coverage and Connectivity in WSNs: A Survey, Research Issues and Challenges. *IEEE Access*. 2018;6:26971-92.

[2] Vijay G, Bdira EB, Ibnkahla M. Cognition in wireless sensor networks: A perspective. *IEEE Sensors Journal.* 2011 Mar;11(3):582-92.

[3] Masrub A. Cognitive radio: The future generation of communication systems. 2014

[4] Joshi G, Nam S, Kim S. Cognitive radio wireless sensor networks: applications, challenges and research trernds. *Sensors*. 2013 Sep;13(9):11196-228.

[5] Shafiee M, Vakili VT. Comparative Evaluation Approach for Spectrum Sensing in Cognitive Wireless Sensor Netwoks (C-WSNs). *Canadian Journal of Electrical and Computer Engineering.* 2018;41(2):77-86.

[6] Han JA, Jeon WS, Jeong DG. Energy-efficient channel management scheme for cognitive radio sensor networks. *IEEE Transactions on Vehicular Technology.* 2011 May;60(4):1905-10.

[7] Mustapha I, Ali BM, Sali A, et al. Energy-aware cluster based cooperative spectrum sensing for cognitive radio sensor networks. *IEEE 2nd International Symposium on Telecommunication Technologies (ISTT)*, 2014 Nov 24-26; Langkawi, Malaysia: IEEE, 2014, pp. 45-50.

[8] Zahmati AS, Fernando X, Grami A. Energy-aware secondary user selection in cognitive sensor networks. *IET Wireless Sensor Systems.* 2014 Jan 16;4(2):86-96.

[9] Liu X, Evans BG, Moessner K. Energy-efficient sensor scheduling algorithm in cognitive radio networks employing heterogeneous sensors. *IEEE Transactions on Vehicular Technology.* 2015 Mar;64(3):1243-9.

[10] Ren J, Zhang Y, Zhang N, et al. Dynamic channel access to improve energy efficiency in cognitive radio sensor networks. *IEEE Transactions on Wireless Communications.* 2016 May;15(5):3143-56.

[11] Ozger M, Fadel E, Akan OB. Event-to-sink spectrum-aware clustering in mobile cognitive radio sensor networks. *IEEE Transactions on Mobile Computing.* 2016 Sep 1;15(9):2221-33.

[12] Usman M, Har D, Koo I. Energy-Efficient Infrastructure Sensor Network forAd HocCognitive Radio Network. *IEEE Sensors Journal.* 2016 Apr 15;16(8):2775-87.

[13] Wu H, Yao F, Chen Y, et al. *Cluster-based energy efficient collaborative spectrum sensing for cognitive sensor network.* IEEE Communications Letters. 2017 Dec;21(12):2722-5.

[14] Kim SS, McLoone S, Byeon JH, et al. *Cognitively inspired artificial bee colony clustering for cognitive wireless sensor networks.* Cognitive Computation. 2017 Apr 1;9(2):207-24.

[15] Samir R, El-Mahallawy MS, Gasser SM, et al. *Exploring the Effect of Various Cluster Structures on Energy Consumption and End-to-End Delay in Cognitive Radio Wireless Sensor Networks.* IEEE Access. 2018;6:38062-70.