e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Conference:01/March-2023 Impact Factor- 7.868 www.irjmets.com
National Conference on Trending Technology for Achieving Sustainable Development Goals
NCTTASDG 2023 Organized by Shri Shankarprasad Agnihotri College of Engineering, Wardha

COGNITIVE RADIO FOR SENSOR NETWORK NODE

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ABSTRACT

Wireless sensor networks are recently used to monitor and control the different parameters in various applications like manufacturing, military, agriculture, home networking, healthcare and smart buildings. Wireless sensor networks operate in the ISM band, which is shared by many other successful communication technologies. Coexistence in the ISM band can degrade the performance of wireless sensor networks. The increasing demand for Embedded Wireless Sensor Network Node, wireless communication introduces efficient spectrum utilization challenge. To address this challenge, cognitive radio has emerged as the key technology, which enables opportunistic access to the spectrum. The main potential advantages introduced by cognitive radio are improving spectrum utilization. Clearly, it is conceivable to adopt cognitive radio capability in embedded sensor network Node, which, in turn yields a new sensor networking paradigm, i.e., Embedded cognitive radio sensor network Node.

I. INTRODUCTION

Similar to the existing WSNs, a CWSN consists of many tiny and inexpensive sensors where each node operates on limited battery energy. In a WSN, each node either sends or receives data or it is in idle state. However, in a CWSN, there would be another state called sensing state where the sensor nodes sense the spectrum to find spectrum opportunities or spectrum holes. Fig. 1 depicts different states for both networks. Among various tasks for each sensor node, the transmission and reception of data are the most energy consuming tasks.

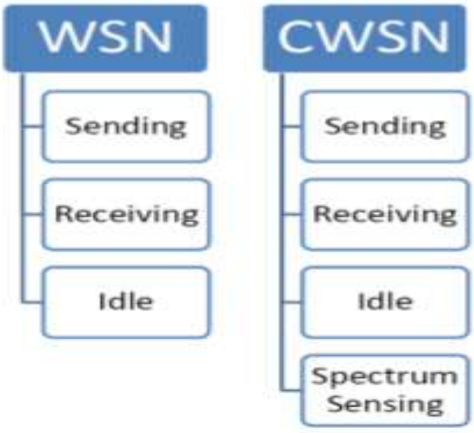

Fig. 1 Different states in a WSN vs a CWSN

II. COGNITIVE RADIO ENVIRONMENT

To access the white spaces of TV band IEEE 802.22 is the first worldwide cognitive radio based standard. Cognitive radio technology based un-licensed use, primarily designed to operate in the TV Whitespaces from 54-862 MHz, on a non-interfering basis with the primary users. "Cognitive radio is a goal-driven framework in which the radio autonomously observes the radio environment, infers context, assesses alternatives, generates plans, supervises multimedia services, and learns from its mistakes. This observe-think-act cycle is radically different from today's handsets that either blast out on the frequency set by the user, or blindly take instructions from the network. Cognitive radio technology thus empowers radios to observe more flexible radio etiquettes than was possible in the past."

III. COGNITIVE RADIO

Cognitive Radio is a radio system which automatically detects and analyze radio spectrum environment to identify temporarily vacant spectrum. Once the vacant spectrum is detected the radio starts its communication in this frequency band without creating harmful interference to the primary users. Cognitive radio is flexible which can change its communications parameters as per channel conditions. Spectrum sensing plays a main role in CR because it is important to avoid interference with PU and guarantee a good quality of service of the PU. 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 networks.

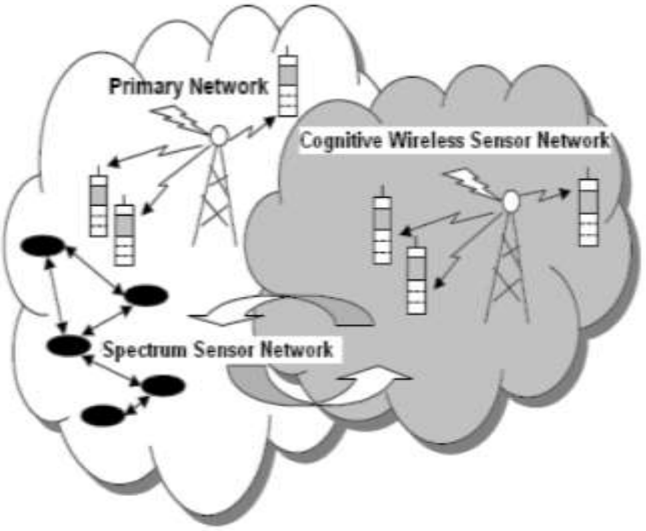

Fig.2 Cognitive Radio Basics

3.1 Spectrum sensing:

Spectrum sensing is one of the major functionalities distinguishing CRSNs from traditional WSNs. Since nodes can operate on spectrum bands of the licensed PUs in an opportunistic manner, they must gather spectrum usage information via spectrum sensing prior to transmission. However, the advantages of opportunistic spectrum access (e.g., more bandwidth, lower error rate due to the ability to switch to the best channel, smaller contention delay) come with the additional power consumption imposed by spectrum sensing and distribution of sensing results. There are various spectrum sensing methods, which are

- Matched filter: This is the optimal spectrum sensing method in Gaussian noise; however, it requires a priori knowledge about PU transmission and additional hardware for CRSN nodes to synchronize with the PU.
- Energy detection: If the measured energy on a channel is below a threshold value, the channel is considered available. Its simplicity and low signal processing requirement make this method very attractive for CRSNs. However, energy detection requires longer measurement duration leading to higher power consumption.
- Feature detection: This method can be used when certain features of the PU transmission (e.g., carrier frequency and cyclic prefixes) are known. It exploits the spectrum correlation of the PU signal, and hence is very robust against variations of noise. However, it has very high complexity; therefore, it may not be suitable for CRSNs.
- Interference temperature: Nodes calculate how much interference they would cause at the PU receiver and adjust their transmission power such that their interference plus the noise floor does not exceed a certain interference temperature level. This method requires a priori PU location information, and is computationally too intensive for a low-end CRSN node.

1.2 Spectrum Decision:

CRSN nodes must analyze the sensing data and make a decision about the channel and transmission parameters (e.g., transmission power and modulation). Spectrum decision methods proposed for cognitive radio networks consider power consumption as a secondary issue. Processing capabilities and the amount of extra control packets to transmit are almost always ignored. Clearly, these settings do not match CRSN characteristics due to inherent constraints of sensor nodes. On the other hand, the spectrum sensing results will be similar in any given locality. If nodes try to access the channel depending only on their individual spectrum decision results, collision probability increases. Furthermore, since nodes run the same algorithm, when a collision occurs, they all try to switch to another channel, leaving the previous channel empty and colliding again on the new channel. Therefore, spectrum decisions in CRSNs must be coordinated to increase overall utilization and maximize power efficiency. Furthermore, a spectrum decision mechanism for CRSNs must have low complexity as well. Coordination and spectrum decision can be handled by centralized or distributed approaches. A sink might be designated as the centralized entity to reach a network-wide optimal spectrum decision, which also imposes additional traffic, resulting in excessive power consumption. However, in distributed coordination, nodes share their spectrum sensing and decision results only with their immediate neighbors or within small clusters. This approach leads to suboptimal utilization, which can still be close to global optimal, and yet is considerably simpler to implement and incurs less communication and power overhead than the centralized approach. Clearly, there are many open research issues for the development of new spectrum decision techniques for CRSNs:

- Spectrum decision parameters: Parameters to be used in spectrum decision (e.g., signal-to-noise ratio, channel capacity, delays and holding times of PUs) must be explored, and new algorithms that yield optimal spectrum decisions must be designed.
- Distribution of control data: Using a network-wide common control channel for coordinated spectrum decision is generally not feasible; however, finding such a channel within a given locality has high probability. Therefore, energy-efficient centralized and distributed methods of sharing spectrum decision in CRSN data must be thoroughly investigated.

1.3 Spectrum Handoff :

When a PU starts using a previously available channel, CRSN nodes 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, reducing communication performance. This fundamental functionality of cognitive radio is called spectrum handoff. When spectrum handoff is needed, first an alternate channel must be determined. Then a receiver-transmitter handshake must be performed on the new channel. Only then may nodes continue their transmissions. All of these additional operations incur long delays and hence buffer overflows, 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 the same time, the development of central and distributed spectrum handoff solutions for CRSNs must be investigated.

IV. CONCLUSIONS

In this paper we review CRSNs formed by incorporating cognitive radio capabilities in WSNs. We discuss advantages of CRSNs, and explore the applicability of the existing techniques for cognitive radio and WSNs in CRSNs along with their difficulties. There are many significant challenges in the realization of CRSNs. We anticipate that this paper will provide better understanding of the potentials for CRSNs and motivate the research community to further explore this promising direction.

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