Analysis of Energy Inefficiency Challenges in Cognitive Radio Sensor Networks

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***Abstract*— One of the challenges faced by Wireless sensor networks (WSNs) is the issue of uncontrollable interference as the spectrum becomes congested due to the current proliferation of wireless devices. Cognitive radio (CR) emerged as one of the promising solutions to overcome the challenges while having the sensor nodes to access the licensed spectrum band. However, these sensors nodes consume huge amount of energy to accommodate the CR functionalities of sensing and switching between the spectrum bands. Consequently, an efficient mechanism is needed to enhance energy efficiency in the resulting cognitive radio sensor networks (CRSNs). Therefore, this paper surveys and analyses energy inefficiency challenges in the realm of WSN and CRSNs as well as some of the proposed approaches. The objective is to comprehend what has been done and how to improve the impeding challenges. We conducted the analysis on 11 related papers in the literature to analyse and identify the existing energy inefficiency challenges and the mechanisms to overcome them. The findings shows that energy inefficiency challenges is due to WSN performing CR capabilities thus, consuming a considerate amount of energy which causes the wireless sensor nodes energy to deplete incessantly. Moreover, several mechanisms have been proposed but more research need to be performed to find efficient solutions that are dynamic with technological advancements.**

Keywords*— *WSN, CRSN, Energy Inefficiency, Spectrum, Users.

I. Introduction

Wireless Sensor Networks (WSN) emerged as a paradigm in the wireless communication as a research interest for both the academics and the industry [1, 2]. Communication occurs as event driven in WSN [3] and existing of plethora of sensor nodes are limited to few meters and are responsible to perceive its environment and relays data for communication in a real-world application [2, 3, 4]. These sensors are battery-powered equipped with the capability to monitor parameters such as temperature, pressure, wind speed and direction, etc. [1]. This technology poses an ad hoc network implementations where there is less human intervention or central management [1]. Moreover, the use of WSN is beneficial in various aspects, to name a few; in the military, industries, Internet of Things (IoT) utilized in smart trends [1, 2, 5, 6]. Moreover, due to the nature of WSN, several challenges are inevitable such as uncontrollable interference, high energy and bandwidth consumption, data processing and compressing methods, quality of service (QoS) and host of other challenges [1,5].

Cognitive radio (CR) emerged as a next generation wireless communication paradigm and an *ad hoc* network to overcome the challenges of spectrum underutilization in a licensed and free spectrum bands. CR make use of free spectrum opportunistically to provide efficient operations [3, 7, 8], having the capabilities of understanding its environment and acting upon it through different phases such as perceiving, planning, reasoning, acting, continuously and autonomously learn through upgrading and updating the studied history [3]. Moreover, its functionalities are based on two users; the primary user (PU) and secondary user (SU) or cognitive user (CU) operating in the unlicensed spectrum but with the privileges of licensed spectrum utilization in the absence of PU. CR devices have the functionalities of spectrum sensing, sharing, mobility and decision [3]. It is these functionalities that made it suitable for solving the challenges faced by WSN to yield Cognitive Radio Sensor Networks (CRSNs). CRSN is a type of networking model based on ad hoc approach operating on distributed sensor nodes with CR functionalities [3, 9, 10] and others such as prediction, fairness, packet routing, reconfiguration, trust and security, power control and so on. The deployment of CRSNs provide lots benefits such as better operating or power/energy efficiency to sustain the wireless sensor nodes battery life time [6, 11]. With the energy constraint faced by WSN to perform CR capabilities [8], it is vital that the lifespan of wireless sensor nodes be sustained since the network operates autonomously without human intervention or any central management.

However, having WSN operating in the unlicensed Industrial, Scientific and Medical (ISM) [8] radio can degrade its performance due to large amount of power, wide deployments and large IEEE 802.11 devices network coverage range [3]. In this case, sensor nodes equipped with CR capabilities can sense the idling licensed spectrum bands and adjust its operating parameters so as to utilize the free licensed spectrum bands. Nonetheless, due to packet loss, WSN utilize the spectrum to retransmit packets hence, causing high energy consumption [3]. That is, given the CR capabilities for channel switching to be supported by the wireless sensor nodes, a considerate amount of energy is consumed. Thus, studies should be conducted for channel accessing to improve energy efficiency in CRSNs [6]. Therefore, in order to proffer solutions to the energy inefficiency challenges faced by CRSNs, this paper performed a survey and analysis of the challenges of WSN and CRs and the impacts on the CRSNs paradigm. The essence is to comprehend these challenges in order to further address them by offering efficient and effective solutions such as new channelling mechanism and others to overcome the energy inefficiency issue. Moreover, insight background on CRSNs and its architecture are discussed. We reviewed papers on existing works in the literature on existing energy inefficiency challenges as well as relevant mechanism already proposed or developed to overcome such challenges.

The remaining parts of the paper are organized as follows: Section II discusses CRSNs, Section III is the relate works, Section IV presents analysis of existing challenges and proposed solutions, Section V presents the paper discussion while Section VI is the conclusion.

II. Cognitive Radio Sensor Networks

CR is a new paradigm specifically proposed to overcome spectrum underutilization in WSN but can still be used for reducing the spectrum bands congestion [6,8,12,16,18]. CRSNs, the specialized *ad-hoc* networks are the recent wireless networking technology formed by incorporating CR into WSN [3, 13]. Thus, the merging is aimed at overcome the spectrum underutilization in WSN [8, 12]. CRSNs constitutes distributed networks made of wireless cognitive sensors equipped with the capabilities of sensing and autonomously communicating the sensory readings dynamically over a shared spectrum bands using multi-hops to route the data to the desired destination until all application specific requirements are met [13]. CRSNs exploits the capabilities of both WSN and CR to provide a much more efficient wireless networks. Not only designed to overcome the spectrum underutilization in WSN, but also to address CRSNs challenges such as processing and communication demands, multihop accessing schemes over unlicensed and licensed spectrum bands [8, 13]. Other potential benefits are improved spectrum efficiency, enhanced transmission and ease of communication amongst heterogeneous WSNs [8].

In spite of these benefits, having WSN operating in unlicensed bands suffers from congested unlicensed bands leading to licensed spectrum being underutilized hence the necessity of deploying CR to overcome such challenges [13]. Moreover, the amalgamation of WSN and CR several limitations such as memory usage, processing capability and power/energy usage inherited from WSNs [8]. For instance, channel accessing and switching is a CR capability which can consume more energy when integrated into WSN. This originates from the SU searching for idling licensed bands in the absence of PU, switching to those bands and then vacating the bands when PU reappears [3]. Several solutions have been proposed and developed based on these challenges. We survey different energy inefficiency challenges and their existing countermeasures in this paper.

CRSN architecture is made up of the following components: the base station, sink, PU and the SU [3, 13, 14, 15]. In both PU and SU, data transmission occurs over an available spectrum in an opportunistic manner using hops and eventually to the sink node [13]. By utilizing CR capabilities, users and sink can exchange extra information such as spectrum allocations, spectrum hand-off aware route with relevance to specific topology and also control data used for group formations [13]

III. Related Works

This section discusses the related works on the analysis of energy inefficiencies in WSNs and CRSNs. There are as follows: Shaik *et al*. [14] comprehensive review on energy harvesting found battery energy leakages as one of the major challenges of WSNs. Moreover, energy depletion affects network performance. Rault *et al.* [18] top-down survey on energy efficiency identified several trade-off between sensor nodes extensions and applications that arises when designing an energy efficient WSNs. Khan *et al.* [19] survey on energy management in WSN found energy harvesting schemes to be more efficient to WSN already produced by battery-powered WSN. Joshi *et al.* [3] discussed that CR device functionalities are found to be consuming more energy and energy harvesting still have their limitations even though they poses as an alternative to overcome battery energy challenges.

Akhtar *et al.* [20] reviewed on how to sustain WSN using energy replenishment using traditional and renewable energy. The review shows that available energy amount has a direct effect on the WSNs functionality, performance and lifetime, thus, battery replacement is not feasible for some scenarios. Hu *et al.* [8] also highlighted that for wireless sensor nodes to function properly with CR capabilities, the CRSNs limitations inherited from WSN such as processing capability, memory usage and power have to be addressed. Moreover, Malhotra *et al.* [12] review on energy based spectrum sensing used in CRNs discussed latest energy techniques on spectrum sensing based on false alarm probability, hypothesis and detection probability in CRNs. They also discussed different techniques for maximizing throughput and system performance for providing efficient network.

IV. Analysis Of Existing Approaches, Challenges and Solutions

This section surveys existing works on energy inefficiency challenges, proposed solutions, the approaches and the tools used.

A. Shah et al. [21]

This paper proposes the cross-layer framework that deploys CR communications to overcome the challenges of power consumptions and also provides support for smart grid applications QoS. The importance was based on the popularity gained by smart grid devices for the next generation of powered systems. Such devices have the capabilities of perceiving and managing electronic devices autonomously as well as managing the power operations equipment efficiently that are being utilized in distribution and power generation.

1) Challenge(s): Multi-paths effects, equipment noise, electromagnetic interference and harsh obstructions in smart grid environments.

2) Proposed solution: They proposed a framework for achieving end-to-end application specific goals within the sensory network. It is also for preserving QoS-Aware communication for smart grid applications based on providing vision. Moreover, it incorporate learning and reasoning between the communication upper layers as well as efficient and opportunistic spectrum accessing at the communication physical layer. The proposed framework uses Lyapunov Drift Optimization for maximizing the utility, Cross Layer distributed control algorithm (DCA) to optimize the MAC and physical layer functions as well as the routing functions.

3) Results and improvements: The proposed schemes is efficient in preserving smart grid applications QoS communication based on; increased number of flows for lower priority classes poses less threat in the performance of higher priority classes for given attributes. It also shows that increasing channels doesn't increase the performance having same ratio and is limited to high variance within the common control channel.

B. Ashraf et al. [22]

This study proposes an energy harvesting mechanism using radio frequency (RF) from transmission within primary spectrum for CRWSNs. The advantages of the proposed work based on energy harvesting is to reduce the carbon emission in the perceived environment, to improve the life span of utilized network and the availability of power to the utilized devices that cannot be recharged with fixed power outlets.

1) Challenges: Simultaneous use of the frequency band lead to interferences and suffering from battery power exhaustion at the receiving nodes.

2) Proposed solution: Energy harvesting transmission mechanism based on the primary spectrum user for CRSNs to avoid battery replacement on sensor nodes. The energy harvesting is based on RF energy rather than renewable energy since is RF energy is controllable. Also, an optimization algorithm is utilized for optimizing WSN performance due to its transmission power from primary transmitters, sensors and primary transmitters' density.

3) Results and improvements: The results shows improved efficiency as the overall success probability and total throughput outperforms the existing schemes. This is because sensors transmission power, primary transmitters transmission power and primary transmitters spatial density were optimized.

C. Jamal et al. [23]

Dynamic Spectrum Access (DSA) is an approach used for CRs to allow SUs to access the idling bands that are underutilized by PUs. Synchronous multichannel schemes and single channel MAC schemes are proposed by other authors to access the underutilized bands. However, this schemes faces problems such as sensing period's challenges, broadcasting over wide network and the use of high priority mechanisms.

1) Challenges: The use of single channel MAC protocol are found to be inefficient in terms of communication the sensor nodes hence lowering the performance of the network and increasing energy consumption.

2) Proposed solution: A novel MAC scheme based on the efficiency of energy and spectrum aware multi-channel MAC protocol is proposed to overcome single channel, synchronous schemes and multi-channel schemes such as Y-MAC and MCMAC multichannel schemes. They all faces sensing periods challenges, broadcasting over wide network and the use of high priority mechanisms. However, the proposed novel MAC scheme uses a spectrum aware asynchronous duty cycle responsible for data transmission and channel acquisition.

3) Results and improvements: A theoretical analyses and simulations were performed in which simulation results shows outperforms the theoretical results. They normalized delays increases at less rate per cycle length, more throughput is obtained at less cycle lengths and less packet size. Moreover, the simulation results show that the proposed scheme is much efficient as compared to MCMAC based on more energy spent on synchronization phase.

D. Akhila and Priya [11]

Despite using CRs to reduce or overcome the WSN challenges which involve utilizing the idling free spectrum bands, there is also the challenge of high energy consumption from sensors when performing sensing and switching of free underutilized bands in the absence of primary users. Thus, this study proposed a scheme based on Dynamic Channel Access with Asynchronous Sleep-Wake Scheduling to Improve Energy Efficiency in CRSNs.

1) Challenges: Uncontrollable interference in the network while utilizing the free licensed spectrum bands due to a plethora of connecting devices.

2) Proposed solution: Joint power allocation and channel accessing schemes are two dynamic channel accessing schemes proposed to overcome intra and inter-clustering data transmission for reducing energy consumption for intra and inter cluster data transmissions. Also, asynchronous sleep-wake scheduling mechanism is used to reduce energy consumption.

3) Results and improvements: Clusters in CRSNs reduces energy consumption, thus preserving the sensor nodes lifespan. However the proposed schemes using sleep-wake scheduling based on clusters is much more efficient in terms of less packet rate per energy consumption than the cluster approach without sleep-wake scheduling. For improvements, a central manager can be used to reduce sensor nodes operation complexities and reduce their energy consumption rate, only managing the channel sensing and accessing then the sensor nodes only accessing them from the cluster head without having to performing channel sensing and accessing.

E. Ren et al [6]

CR allows the wireless sensors network to utilize the spectrum with less interference occurring during sensing and switching between spectrum bands. Without proper channelling accessing mechanisms, spectrum bands faces congestion problems resulting to uncontrollable interferences. Thus, this paper focuses on dynamic channel access problem to find a solution of overcoming energy inefficiency within the clustered CRSNs.

1) Challenges: Issue of having sensor nodes consuming high amount of energy to perform sensing and switching operations.

2) Proposed solution: Dynamic Channel Access using two accessing and sensing schemes (i.e. joint power allocation and channel accessing scheme) used within intra and inter clusters of CRSNs for data transmission and obtaining optimal energy efficiency. This is to determine the conditions in which a sensor node can sense and switch to licensed bands.

3) Results and improvements: Simulations was performed to demonstrate the efficiency of the proposed schemes to improve energy consumption in CRSNs. Results shows that the proposed scheme significantly reduces energy consumption during transmissions as compared to other researchers proposed schemes. For improvements, a mechanism such as sleep and wake and energy harvesting mechanisms can be used to allow only sensor nodes to transmit data set to active while others are inactive to enhance energy consumption rate.

F. Sarma et al. [24]

This paper proposed a novel chain routing protocol that reduce energy consumption in the network.

1) Challenges: Routing challenges in CRSNs namely; the design of efficient energy routing protocols for preserving network lifetime and joint node-channel assignment for enabling DSA.

2) Proposed solution: Energy balanced routing protocol which organizes the wireless sensor nodes within the field in a form of a chain where only the sensory data is relayed to the sink(s) using different chains following a balanced energy manner. This solution is to leverage network and improving energy usage of sensor nodes. The proposed scheme make use of the following approaches in five different phases: localization, synchronization, chain formation, energy balanced data forwarding and chain reformation.

3) Results and improvements: Simulation results shows energy efficiency for proposed scheme outperforms the existing Energy and Cognitive Radio aware routing protocol (ECR). The proposed scheme transmits more data per energy consumed and less energy is consumed when the network size increases as well as the more nodes remains alive with increase in time. For future work to improve the proposed scheme, an analytical modelling of the proposed energy balancing routing protocol can be used together with protocol rigorous analysis.

G. Mahmood et al. [17]

WSN can used as a promising solution to monitor real life events such as environmental natural disasters. An event-driven WSN is one of the promising technologies that can implemented in a clustered networking environment. This paper proposed an approach to assessing a structural health using cellular networks as a primary network. This kind of event-driven mechanism is used to detect seism activities within buildings.

1) Challenges: Seism Activities

2) Proposed solution: An event driven WSN using CR capabilities for gathering data and reporting information due to seism activity in building. It utilizes white spaces using a cellular network under CRSN based on average energy consumption and packet delays. This is geared towards providing a network with efficient uses of resources for buildings and offices using cellular networks as a primary network.

3) Results and improvements: Simulations were conducted to analyse the performance of the average cluster formation and average consumed energy for WSN both in steady states and cluster formations. Results show efficiency in using cellular networks as primary network. It is more suitable for data transmission to the secondary network without hindering the primary network performance. Moreover, WSN is also capable of sending relevant seism activities information for experts' analysis. For improvements, analysis should be conducted on interference due to seism activities in both primary and secondary networks to determine which network suffers most from interference as well as improving the network to increase accuracy of data transmitted.

H. Zhang et al. [25]

This study focuses on a new paradigm of Energy Harvesting Cognitive Radio Sensor Networks (EHCRSNs) that improves the capabilities of energy harvesting within heterogeneous cognitive sensor networks. The networks makes use of spectrum sensor nodes to cooperatively and efficiently sensing underutilized licensed channels and the data sensor nodes that is responsible for resource allocations such as time, power and channels.

1) Challenges: By using Harvesting Cognitive Radio Sensor Networks (HCRSN), the traditional CR models and energy harvesting dynamics faces challenges of scheduling the utilized spectrum sensor and data sensors resource allocations.

2) Proposed solution: Proposed resource allocation scheme based on HCRSN to have the sensor and spectrum sensors energy sustained. It uses two algorithms operating one after the other; a Spectrum Sensor Scheduling (SSS) Algorithm for allocating spectrum sensors the channels. This is important to ensure that detected average available time for channels can be maximized considering EH dynamics while protecting PU transmissions and a Data Sensor Resource Allocation (DSRA) Algorithm.

3) Results and improvements: Results shows that harvested energy is much more efficient than battery-powered energy hence improving the life-span of the sensor nodes. That is, it also shows efficiency of using primary network channels occurring in real time using harvested energy and optimized scarce resource allocations to the battery powered sensor data nodes. For improvements, future work can be based on analysis of routing protocol designs and channel allocation in energy harvesting multihop HCRNS based on different time rates of energy harvesting as well as how the sensors threshold can be detected adaptively.

I. *Lee and Zhang [26]*

This study focuses on a new technology known as Cognitive Wireless Powered Communication Network (CWPCN) where secondary WPCN utilizes the same spectrum with its Wireless Information Transmission (WIT) and Wireless Energy Transfer (WET) using an existing communication system.

1) Challenges: Under-optimization of the total throughput for CWPCN within each sensory model under ITC/PRC due to less optimized time and power allocation in secondary WIT, WET and CWPCN.

2) Proposed solution: Proposed new CR with enabled secondary WPCN is proposed for spectrum sharing within a shared primary wireless communication system. It uses two coexisting spectrum sharing models (underlay and overlay)-based WPCNs. Both models are used for maximizing the total throughput of CWPCNs by allowing the transmission be optimized under varied constraints used to protect PU transmissions.

3) Results and improvements: The experiments conducted to compare the total throughput of CWPCN against the rate that can be achieved for the PUs using two proposed coexisting models. The results shows that the overall total throughput decreases when path loss exponent increases. That is, the throughput increases when the hybrid access point transmission power is maximized. For future work, a general CWPCN setup, full duplex systems and user fairness systems can be used. To create multileveled equations, it may be necessary to treat the equation as a graphic and insert it into the text after your paper is styled.

J. *Yin et al. [27]*

Cooperation in cognitive wireless sensor communication might be key to preserving the energy consumption of the network. But having model that supports both powered communications and efficient spectrum sharing models can leverage the energy usage. Thus, CWPCNs is being proposed in this paper to provide an optimal design of an energy efficient model.

1) Challenges: Energy optimization inefficiency for uplink in CWPCN which affects the cooperation between secondary and primary systems for both decode-and-forward (DF) and amplify-and-forward (AF) protocols.

2) Proposed solution: A cooperative CWPCN is proposed to maximize the concept of cooperation between SUs and PUs used in early completion of primary and secondary Wireless Information Transmission (WIT). CWPCN proposed solution utilizes two approaches; AF and DF protocols for maximizing the uplink and the energy efficiency. A suboptimal solution is also deployed to counter the unavailable information with channel condition amongst primary transmitter secondary users.

3) Results and improvements: For spectrum sharing and cooperation, the DF protocols shows better efficiency than AF protocol, whereas the proposed suboptimal solution outperforms the optimal solution. Improvement can be by grouping the primary transmitters, primary receivers and hybrid access points to provide better spectrum cooperation sharing as it still remains an open challenge.

K. *Sakr and Hossain [28]*

Despite the cognitive radio capabilities of efficient spectrum wireless communication, there is still a need to enhance energy efficiency so as to sustain the network performance and reliable communication channels. Thus, having a proposed model based on radio energy frequency energy harvesting from ambient interference; this enables a model for energy-efficient wireless communication.

1) Challenges: Improving energy efficiency of CRs in cellular network communications.

2) Proposed solution: Proposed a Cognitive and Energy Harvesting-Based Device-to-Device (D2D) model based on cellular networks communications. The study focuses on two policies for spectrum accessing for cellular communications using downlink or uplink. They are Random Spectrum Access (RSA) being used for selecting available channels including channels utilized by D2D transmitters and a Prioritized Spectrum Access (PSA) that allows the D2D channels to be utilized when active channels are being occupied.

3) Results and improvements: Cognitive D2D power consumed by using harvested energy has a better performance. It shows cognitive channel has better D2D users outage probability both in spectrum access policies under the same signal-to-interference-plus-ratio outage requirements. Also prioritized access policies have better D2D users' performance as compared to random access policies. Moreover, the uplink channel outperforms the downlink in terms D2D users' congested networks. The performance analysis also shows that PSA and RSA provides the same outage probability for cellular users.

V. DISCUSSIONS

We have performed analysis of CRSN challenges of energy inefficiency challenges and solutions proposed in the literature to overcome them. The results of the analysis shows that energy efficiency is one of the major key aspects of CRSNs that differentiate it from other networks. However, energy consumption poses a serious problem for battery powered devices such as wireless sensor nodes for CRSNs. This is because these nodes operates autonomously and continuously as they are no mechanisms to restrict energy consumption when nodes are inactive. For instance, battery-power exhaustion is due to simultaneous communication between the sensor nodes and the base stations as well as uncontrollable interference where the channel is congested. Others include the failures to vacate the SUs from the licensed spectrum when PUs reappears, routing challenges due to hops and redirecting the data to the desired destination, scheduling the sensor nodes and data resources to be allocated fairly to the users, and under-optimized throughput. All these tends to degrade the network performance and affects the QoS communication between the sensor nodes and the base stations.

central management mechanism that can handle only channel sensing and accessing and have only sensory node for sensing the data. The importance is to enhance cluster energy consumption by reducing the wireless sensor nodes operation complexity, improve network performance and better resource allocations. Table I summarized the different energy challenges faced in CRSNs, the approaches, solutions and improvements.

TABLE I. EXISTING CRSN ENERGY-INEFFICIENCY CHALLENGES AND PROPOSED SOLUTIONS

Ref.	**Challenge**	**Proposed Solutions**	**Approach Used**	**Tool Used**	**Implementation**
[21]	QoS WSN based grid application devices: Multi-Paths effects, Equipment noise, Electromagnetic interference, Harsh obstructions	QoS-Aware communication for grid applications	Lyapunov Drift Optimization for utility maximization Cross Layer Distributed Algorithm (DCA) for MAC and PHY layer optimization and routing functions	NS-2	Smart grid applications
[22]	Battery-power exhaustion due to simultaneous communication	Energy Harvesting transmission mechanism	Optimization Algorithm to maximize the WSN overall probability.	MATLAB	N/A
[23]	Sensing period challenges, wide broadcast and high priority mechanisms due to single channel MAC protocol	Energy Efficient and Spectrum aware multi-channel MAC protocol	Spectrum aware asynchronous duty cycle responsible for data transmission and channel acquisition	N/A	N/A
[11]	Uncontrollable interference	Dynamic Channel Access	Asynchronous Sleep-wake scheduling mechanism for inter and intra clusters	NS-2	N/A
[6]	Uncontrollable interference	Dynamic Channel Access	Joint power allocation and channel accessing scheme for inter and intra clusters	OMNET++	N/A
[24]	Routing challenges	Energy balanced routing protocol	Localization, Synchronization, Chain formation, Energy balanced data forwarding, Chain reformation	MATLAB	N/A
[17]	Seism Activities	An event driven WSN using CR capabilities	N/A	N/A	Conventional cellular systems
[25]	Scheduling the utilized spectrum sensors and data sensors resource allocations.	Resource allocation scheme for Harvesting Cognitive Radio Sensor Networks (HCRSN)	Two algorithms operating in tandem: Spectrum Sensor Scheduling (SSS) Algorithm and Data Sensor Resource Allocation (DSRA) Algorithm	MATLAB	N/A
[26]	Under-optimization of the total throughput for CWPCN within each sensory model under ITC/PRC	A new CR with enabled secondary WPCN is proposed	Two coexisting spectrum sharing models (underlay and overlay)-based WPCNs	N/A	N/A
[27]	Energy optimization inefficiency for uplink in CWPCN	A cooperative Cognitive Wireless Powered Communication Network (CWPCN)	Amplify-and-Forward (AF) and Decode-and-Forward (DF) protocols	N/A	N/A
[28]	Energy inefficiency of CR in cellular network communications	A Cognitive and Energy Harvesting-Based Device-to-Device (D2D)	Random Spectrum Access (RSA) and Prioritized Spectrum Access (PSA)	Stochastic geometry	Device to device communication in cellular networks

With the highlighted challenges, several mechanisms have been proposed such as the dynamic channel access which is famously used to overcome uncontrollable interferences, energy harvesting mechanisms such as using renewable energy or radio frequency energy to avoid battery-power exhaustion. These mechanisms are mostly proposed for clusters and using approaches such as asynchronous sleep-wake scheduling mechanism for inter and intra clusters. It allow only active nodes to transmit data where other are put to sleep mode, the joint power allocation and channel accessing schemes for inter and intra clusters. However, these mechanism can still be further improved for better energy efficiency by allowing a Energy inefficiency can degrade the performance of the whole network hence affecting the QoS communication between the sensor nodes and the base stations.

VI. CONCLUSION

This paper presented energy efficiency challenges that confronts CRSN specifically brought about by WSN. The paper provided discussions on some energy inefficiency issues and existing proposed solutions to improve the energy consumption. The discussions were based on in-depth reviews performed articles from the literature. The analysis results revealed that though several solutions have been proffered, CRSN energy efficiency still needs further and concrete research to enhance it. Thus, there is the need to enhance existing energy consumption mechanisms of CRSNs as well as developing new mechanisms with cutting-edge technologies. These mechanisms should be able to sustain the sensor nodes' lifespan, improve the energy consumption to perform CR functionalities while maintaining a reliable communication and better resource allocations. To this end, our future work is to address this challenge by designing and developing an improved mechanism to curb the energy inefficiency nightmare in CRSN.

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