Journal of Science and Technology
ISSN: 2456-5660 Volume 6, Issue 04 (July-August 2021)

www.jst.org.in *DOI:https://doi.org/10.46243/jst.2021.v6.i04.pp258-273*

A survey on opportunistic routing and channel assignment scheme in cognitive radio ad hoc networks

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To Cite this Article

G B V Padmanadh, Dr. P. Vamsi Krishna Raja, Dr.J.V.R.Murthy "**"A survey on opportunistic routing and channel assignment scheme in cognitive radio ad hoc networks"**", *Journal of Science and Technology, Vol. 06, Issue 04,-July-August2021, pp.:258-273.*

Article Info
Received: 26-07-2021 *Revised: 12-08-2021* *Accepted: 19-08-2021* *Published: 28-08-2021*

Abstract:

In terms of Cognitive Radio (CR) technology, Cognitive Sensor Networks (CSNs) vary substantially from conventional WSNs. Modification of transmitter settings is needed for CSNs based on the interaction with the surrounding environment. However, routing is an essential component, and routing methods differ from those used in other networks. On the spectrum-awareness feature the routing system should be able to comprehend the changing spectrum resources in order to create a connection. A trustworthy forwarding path Packet losses and node connection are severely impacted by spectrum unavailability. The buffer is full. The length of time packets are dropped has an effect on the data delivery rate and network lifespan. In terms of routing, phase, this flaw aims to extend the life of a network. Power dissipation and packet loss are calculated based on the spectrum connections. We've looked at different routing methods for cognitive sensor networks, including drop ratio. These techniques will assist in lowering the cost of living. Drop ratio and guarantee that the data can be handled by nodes with a low dropping ratio. As a result, the network's lifespan and energy consumption are reduced. The efficiency of the system will improve.

Keywords: Cognitive Sensor Networks, Packet dropping, Data delivery, Network lifetime, Packet drop ratio, Energy efficiency

1. Introduction

The Internet of Things (IoT) has evolved into a critical networking paradigm that enables physical things to communicate with one another. In the future, industrial, workplace,

www.jst.org.in DOI:https://doi.org/10.46243/jst.2021.v6.i04.pp258-273

and home gadgets will be capable of detecting, transmitting, and analysing data [1]. IoT solutions must deal with a variety of spectrum and energy constraint problems as the number of wireless devices grows exponentially. In the Internet of Things, spectral and energy efficient methods are needed for a variety of sensing devices that are dealing with these issues. The use of opportunistic spectrum sharing is regarded as a possible option, and spectral efficiency is achieved [2]-[4]. For different applications, a high number of linked devices may be supported. Unlicensed devices (secondary users) have been able to utilise cognitive radio (CR) as a crucial technology for opportunistic spectrum sharing while coexisting with a licenced network (primary network) [1], [2], [5]. People who subscribe to the main network are referred to as primary users (PUs). In CR sensor networks (CRSN), any non-continuous spectrum may be utilised to increase spectrum efficiency [6]. Wireless energy harvesting may offer energy supply from radio frequency (RF) signals, which improves network lifespan and energy efficiency. Sensor nodes in wireless energy harvesting and data transmission transform incoming RF signals into DC power and perform other functions. There are two potential scenarios for wireless energy harvesting: I energy harvesting from ambient RF signals by sensor nodes, and ii) deploying specialised energy transmitters in the sensor nodes' proximity. Various research groups have explored energy efficient solutions for IoT [7]-[10]. The sensor nodes in the prototype described in [11] are powered by ambient RF energy.

In [12], energy harvesting from the spectrum range of radio waves spanning from 3 KHz to 300 GHz is proposed for use in body area networks. A work-on-demand protocol is proposed for energy management. Energy harvesting methods have been described in [13]-[15], which collect energy from ambient RF signals to meet the energy needs of sensor nodes. For IoT, CRSN may utilise alternate spectrum resource options to enhance spectrum utilisation [16]. Various deployment patterns have been examined [17] and performance comparisons have been provided to assess the performance of CRSN for IoT. Intelligence and cognition have been created and used in CRSN [18], [19] to achieve the benefits of user needs and network efficiency. Along with the conventional capabilities, the processing of spectrum sharing and spectrum sensing activities has needed more energy for sensor nodes in the CRSN [20]. Energy harvesting may be used in CRSN to meet these needs and improve energy efficiency. The channel assignment and sensor node selection methods should be redesigned to include energy harvesting in CRSNs for improved performance in spectrum fluctuations and power management, based on energy variations (difference between energy consumption and collected energy).

Sensor nodes in the licenced bands in CRSN can detect vacant channels using spectrum sensing, and communication channel estimations may be made using spectrum decision. The operational channels change the spectrum hand-off when PUs come on the communication channel. In a dynamic spectrum environment, nodes collaborate with their neighbours in a multi-hop fashion to transmit event data from the source to the destination. Despite resolving

www.jst.org.in DOI:https://doi.org/10.46243/jst.2021.v6.i04.pp258-273

the difficulties of dynamic spectrum via CR features, CRSN has been constrained by energy and hardware concerns borrowed from WSN.

Earlier solutions did not take into account CR functions or solve the difficulties of dynamic spectrum for WSNs. The suggested solutions for CRN do not take into account the hardware and energy constraints. We needed to come up with new methods to deal with these problems. It is necessary to do more study in the field of CRSN, which has recently piqued the attention of the scientific community. Recent research has focused on connection, clustering, and route creation. [21], [22], [23], [24], [25], [26], [One of the most important study areas in sensor networks is clustering, which involves sensor nodes forming groups to control system topology and improve system stability. Various clustering studies for wireless ad hoc networks and WSNs have been published [23], [24], [25], [26], [27]. By clustering in current systems, the whole network is divided into self-organized clusters, with each cluster controlling one of the cluster members, known as the cluster head (CH), acting as the cluster's central entity. It aggregates data from other member nodes of a cluster before sending it to the next node to sink in a routing route. CH chooses clustering methods for WSNs based on the residual energy of nodes [28]. Clustering methods may contain two nodes inside a cluster only if one common channel is available, and they cannot be used for CRSN. Because of the changing radio environment, re-clustering has happened, and the schemes alone cannot guarantee stability. The proposed distributed and energy-efficient event-driven cluster-based routing approach focuses on making PU operations with CRSN more robust. The CRSN features adapt in a routing protocol that sends event samples from detecting nodes to the sink based on inter and intra-cluster communication. The optimum number of clusters is calculated in order to reduce communication power usage.

Intra-cluster aggregation is done using CHs in a spectrum aware clustered structure, and efficient intercluster relaying is performed via gateways while keeping energy consumption in mind. Clustering is used under the constraint of spectrum aware to reduce intra-cluster communication power and intra-cluster distances. CHs have selected for each cluster and gateway nodes have chosen for inter-cluster connection based on available channels, node residual energy, and distance to sink node. These CRSNs have been driven by dynamic spectrum access (DSA), which allows for the provision of necessary performance in applications by dynamically altering operational settings and adapting to channel conditions.

In CRSN node 1, which has some data to transmit for PR nodes, which are priority nodes, a three-step procedure known as the cognitive cycle must be completed [29]. The primary function of channel sensing is to comprehend the present channel state. Channel sensing data have been evaluated for communication to select the appropriate channel or tuning to make choices by CRSN node. The CRSN nodes may access both unlicensed and licenced bands, and they supply opportunistically without interfering with PR nodes. When any PR node displays on the same channel in the CRSN communication, the CRSN node is obliged to vacate the channel immediately for PR communication. For WSNs, the CR feature enables them to impose certain constraints on how they use the effective spectrum. The difficulties need be addressed in order for the CRSN to succeed in the future. Large bandwidth is required to meet the data rate needs in CRSNs since multimedia is an important component of all applications, and CRSNs offer seamless communication for those applications based on unlicensed opportunistic access [30]. CRSNs improve based on CB by offering a wide bandwidth to opportunistic users in order to get access to the benefits of many contiguous channels that are free of PR activity. Multiple contiguous channels have been utilised in high bandwidth applications that integrate utilising the CB. The different interfaces are installed on equipment that conduct parallel spectrum hole detection for numerous networks and utilise them as needed [31]. Although CB is a popular technique for CRSNs, CRNs, WLANs, and WSNs, it can only offer the required performance if it makes correct decisions based on PR activity. The spectrum use in the Primary Radio (PR) activity is approximated by PR nodes. The channel is selected using the channel sensing method. If the CRSN nodes detect the channels that may be utilised for CB, they are said to be CRSN nodes. If any PR node appears on any bond channel, the CRSN nodes do periodic channel sensing during communication. The CR node must cease the conversation, break the connection, and exit the channel. The CRSN node will have to overcome interference before being able to identify the PR node. The CRSN transmissions are severely disrupted as a result of the bonds breaking and forming often. Certain network requirements are difficult for CRSN nodes to fulfil. The significance of RIT, on the other hand, is highlighted. The CRSN nodes may satisfy the QoS requirements and reduce PR node detrimental interference if channels with the longest RIT with the highest likelihood are selected. The channels with the longest remaining idle time are best for CRSN nodes. Using CRSN nodes, unwanted interference may be reduced, and certain QoS criteria can be met.

2. Literature survey

The authors provided an outline of energy management and its related difficulties for IoT in [21].For IoT, energy management is divided into two categories: energy harvesting activities and energy-efficient solutions. Energy-efficient solutions for lightweight protocol design, predictive models, and sleep and idle states for energy usage are all part of the optimum scheduling. [37] presents a thorough review of energy harvesting sources, their advantages, and uses. Two receiver designs have been introduced in [38], including power splitting and time switching. The sensor node chooses whether to use the received signal for energy harvesting or information, and the signals are split into two streams, one for the RF energy harvester and the other for the information receiver. [39] offers an integrated architecture for energy harvesting and spectrum management to address the difficulties of data rate needs in complex and contemporary applications. Consider energy harvesting for CR networks to address energy shortage. Energy is discussed in [40].

Harvesting is a concept introduced for CR networks in which an optimum spectrum sensing method is proposed for increasing throughput under energy causality limitations and spectrum access collisions. In [41], a cooperative method for wireless energy harvesting and spectrum sharing in 5G networks is proposed. With the circumstances of energy harvesting and data rate, an optimization issue arises for both SUs and PUs in order to improve throughput.The authors of [42] suggest a channel selection method for CR networks in order to recover better throughput for SUs in fading channels while maintaining energy neutrality requirements. A CR system has been suggested based on slotted mode, which considers the harvesting of energy by SU from the ambient environment. System settings may be adjusted to improve the trade-off between harvesting sensing and throughput. [44] introduces guard and harvesting zones in CR networks. If a node is within the harvesting zone, it collects energy, and if it is outside the guard zone, it transmits data.

The suggested method does not accomplish energy balance, but it does optimise throughput. The PU behaviour does not take into account channel allotment. Different methods for optimal energy management have been investigated in cluster-based CRSNs. For RF energy harvesting based CRSN, [45] offers a channel pairing method, as well as a two-level residual energy and channel quality aware sensor node categorization system. They may be used to determine which sensor node is the best for reporting. [46] implements the low-energy adaptive cluster hierarchy (LEACH) method for CRSN, which rotates the cluster head (CH) to accomplish energy management across different sensor nodes. Even though the algorithm complexity is minimal, energy efficiency is not achieved with the uneven distribution of CHs. The authors of [47] looked at a reinforcement learning-based trust and reputation model for selecting the CH in CR networks that identifies harmful SUs. An event-driven spectrum aware clustering for CRSNs suggests and determines potential sensor nodes for CH based on their distance from the event and sink [48]. CH selects suitable nodes based on their distance from the sink, node degree, and available channels. In [49] and [50], CH selection methods suggested that the CH be chosen based on weight. The energy efficiency of clusterbased CRSNs increases with dynamic channel access, as shown in [51]. The sequential channel sensing and accessing methods have been developed for CRSNs to achieve energy efficiency for both inter-cluster and intra-cluster data transmission. The methods of probability-based channel idle time estimate have been shown in [52]-[54]. Various probabilistic models are used to predict future availability. These methods have limitations in terms of idle time prediction, but they perform better in terms of predictability.

[55] presents a comprehensive review of the current node clustering method with performance comparison.In [56], an energy-efficient and learning-inspired channel choice method for CSNs was developed, enabling access to CRSN sensor nodes based on prior data about energy consumption rate and efficiency. The advancement of network lifespan and energy efficiency for multi-channel CRSN is discussed in [57]. The packet size adjusts in the scheme, in addition to the provision of energy aware channels for sensor nodes.

The transition probabilities were determined using a two-state Markov chain and a maximum-likelihood method for modelling main users' behaviour. SCR (spectrum aware

www.jst.org.in DOI:https://doi.org/10.46243/jst.2021.v6.i04.pp258-273

cluster based routing protocol) is proposed in [58]. The ability to participate in the construction of a route by sensor nodes has been restricted in order to save power consumption. Because SCR is not an event-driven routing protocol, clusters form in the network under the constraint of spectrum awareness, which leads to frequent re-clustering in a dynamic radio environment. For CRSN, a distributed spectrum aware clustering method is proposed [59]. In spectrum aware circumstances, restricted clustering is used to cluster CRSN nodes. [60] proposes an energy and cognitive radio aware routing system (ECR) based on the on-demand distance vector concept (AODV). The idea provided in [62] is expanded for the mobile situation [61]. At various places, multiple channels are accessible in SUs [63]. One of the difficulties for spectrum sensing is shaded and fading settings, which may reduce sensing accuracy. The Cooperative Spectrum Sensing (CSS) has utilised [64], [65], and [66] to solve the performance deterioration.

The allocation issue in CRSN is centred on deciding the proper grouping of SUs and allocation of SUs to utilise the PU channels for inter-cluster and intracluster communication. To solve the related difficulties with CRSN and decrease energy usage, a distributed event-driven cluster-based routing proposal is proposed. Clusters are created by decreasing re-clustering frequency while creating a network based on a greater number of common routes between and within clusters. Among prospective nodes, the trustworthy gateway nodes have selected to have greater energy with neighbouring clusters and more common channels, as well as being closer to the sink node. The use of CBs in CRNs, WSNs, and WLANs has been considered. The CB difficulties have been discussed when building the CRSNs.

In WSNs and WLANs, several contiguous channels are combined by CB utilising RIT-based CB to provide a higher bandwidth for users [67]. Wireless local area networks (WLANs) have been implemented to offer users with continuous, seamless assistance. All wireless devices that get vendor support are powered by WLAN.

Internet assistance is available to users in a variety of locations, including the market, hospital, workplace, and home. WLANs have been utilised to offer internet access to users, thus performance may be improved by using the CB.

The new standard enables CB for IEEE 802.11n WLAN to provide high bandwidth to consumers. In a WLAN, all users share resources equally, and the bond size varies depending on the number of users available. When there are more users and network resources are needed, the bond size will be reduced in order to offer more users with internet access. When there are fewer users, the bond size may be increased. In [68], the bandwidth in wireless networks is improved by examining several approaches, and the efficacy of the CB method is emphasised. Some specific events are sensed by deploying WSNs, and their parameters are sent to the actuator or central station in a multi-hop manner [69]. Because WSNs have a limited range of communication and lifespan, their deployment has been dense. With a limited communication range, the lifespan of WSNs may be extended. IEEE 802.15.4, which

www.jst.org.in *DOI:https://doi.org/10.46243/jst.2021.v6.i04.pp258-273*

is the current WSN standard, does not support it by default. WSNs have utilised the industrial, scientific, and medical (ISM) band for communication, thus efficient spectrum use is needed to minimise interference.

3. Routing in Opportunistic Cognitive Radio Networks

Khalife et al., [93], present a reactive source-based routing protocol for CRNs as well as a new routing parameter. It uses a probabilistic description of the available channel capacity to implement. Although the most likely path (MPP) does not ensure that the bandwidth demand will be fulfilled, it is determined by the routing parameter. In this instance, an augmentation phase is used, which involves adding extra channels to the bottleneck connections. The resultant route fulfils the bandwidth requirement with a specified probability.The PR probability distribution to the user interference of CR across a channel at any node is used to calculate the available capacity.

The control channel is used for node coordination, while the source is used whenever an application asks a capacity requirement. All link probabilities have been calculated depending on demand. After calculating all connection weights, the source uses a Dijkstra-like method to find a path to the destination. MPP considers the likelihood of meeting demand as well as stability. When a Dijkstra-like algorithm reaches one of the two states listed below, it stops working.

1. The overall capacity on MPP's each connection will be higher than the demand.

2. Any route is unsuitable for the destination if the total projected capacity on two nodes across all channels is insufficient to meet demand once the augmentation is processed. As a result, it is inaccessible.

4.Local Coordination-Based Routing

Local coordination is a kind of improvement technique that is applied when nodes on a routing route cross. Local coordination is started if nodes are assessing both the flow accommodation and redirection process. The flow redirection or accommodation is chosen by the nodes based on the neighbourhood interaction and assessment findings.

Yang et al., [94], present a system for on-demand routing and spectrum assignment that interacts with multi-frequency scheduling and communicates local spectrum data at each node. To prevent SOP inconsistency, AODV changes the protocol to include a method for exchanging SOP across nodes via a shared control channel. Traversing flows are recognised at each node, and RF band usage is calculated for multi-flow multi-frequency scheduling. The node delay and route delay along the way, as well as the path cumulative delay estimates, indicate the back off and switching delays. For multi-frequency traffic, a local coordination method is used for load balancing on crossing nodes. Despite the frequency bands irregularity, it is equipped with a conventional wireless interface as well as a CR transceiver to guarantee the routing messages are sent successfully at each node. Each node's SOP data is sent to its network layer. The local coordination is implemented on each node of multi-hop CRNs.

5. Multi-path Routing

In multi-path routing, several routes are found for every destination, and some of the best paths are chosen from among the discovered routes using numerous criteria. Multi-path routing offers the benefits of reduced main to secondary user disturbance and increased bandwidth.

Existing multi-path routing methods cannot be adapted for conventional WSNs in CRNs because they do not take into account the cohabitation of main and secondary users, nor the variety in spectrum availability. MRSA [95] is the most used multi-path protocol, and it is used by CRNs to minimise interference and inter-path congestion. The main users' interruption has been handled with decreased degradation thanks to the traffic flow dispersion across various routes.

The round robin method is used to distribute traffic, however it is ineffective. When several routes do not have any interfering bands between them, MRSA revises the notion of "spectrum wise disjointness," and these paths are spectrum wise disjointed. In MRSA, a total of N channels is assumed for data traffic, with signalling sent over the same channels as data transmission. The RREQ message with new RREQ ID broadcasts by the source node and its band radio use table (BRT) attaches. The dynamic source routing (DSR) [99] has been utilised for route discovery and the RREQ message with new RREQ ID broadcasts by the source node. Whether RREQ is received by an intermediate node before forwarding, the RREQ ID is checked to see if it is a new one. If this is not the case, the hop count is calculated from the source. When RREQ has less hops than the preceding RREQ, it will add its BRT and forward it. The destination will get the same RREQ from various routes. Each connection is assigned a band and radio, and all potential routes are evaluated based on available bandwidth. To deal with the main users' unexpected arrival, the DSR's RERR message, which is part of route recovery, is extended.

5. Tree Based Routing

A tree structured network allows the tree based routing protocol based on a root configuration. The tree based routing system, which is a centralised routing scheme, is controlled by a single network object known as the Base Station. The network architecture among CR stations may be built based on the setup of a cognitive BS as root.

For wireless mesh networks, a tree based routing protocol (TBR) is proposed [96], which is an enhanced protocol of cognitive tree based routing (CTBR) [97]. Local and global decision methods have been used to choose a path. The global choice scheme selects the route with the best global end-to-end metric, whereas the local decision scheme selects the optimal interface with the least load. Multipath routes with the same global end-to-end metric may exist for the same destination. The load measurement was utilised to choose the end-to-end route using the local decision method.

CTBR employs the TBR routing method, which sends a Root Announcement (RANN) message utilising a root on a regular basis in order to construct a tree. The node caches and receives the RANN, which it considers to be the possible parent, and the RANN rebroadcasts with the modified cumulative parameter. A parent node will select a node based on the best parameter, such as the hop count for the route to root, among all possible parents. To register with root, each node contains a known path to root and sends a route reply (RREP). The message is sent by any intermediate node that receives REEP to its parent node and updates the routing table based on the RREP source node selected as its destination. As it learns all network nodes, a tree eventually forms. However, a link quality is included to make the TBR for CRNs flexible.

6. Conclusion

Different innovative routing techniques studied and calculated the drop factor based on the average hop count link and random number produced at each node, depending on the drop factor of existing connections between nodes. PUs in a network broadcast control packets. When the control packets are received, the connections with a smaller drop factor opt to use the PUs to verify spectrum availability and connect to the destination nodes. We've come to the conclusion that these new routing methods will decrease energy usage while also increasing network lifespan. The overhead of a network employing these routing techniques for CSNs is reduced by adding extra algorithms at nodes.

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