# Analysis of Secure Cognitive Radio Network with Optimal Resource Management

T. Vijaya Kumar [1], Dr. C. Sharanya [2]

[1] *Research Scholar, Department of Electronics and Communication Engineering, VISTAS, Vels University, Chennai, Tamil Nadu, India.* vijaykumar4792@gmail.com

[2] *Assistant Professor, Department of Electronics and Communication Engineering, VISTAS, Vels University, Chennai, Tamil Nadu, India.* sharanya0608.se@velsuniv.ac.in

**Abstract:** During the last decade, Cognitive Radio Network (CRN) technology has been a significant advance in addressing the ever-increasing spectrum demand. As the number of licensed and unlicensed users in a network rises to complete a certain activity, the information exchange between various types of traffic becomes more complex and difficult. Congestion in CRN is also caused by the conflict among several users for channel access (PUs and SUs). In a very crowded network, many applications perform badly owing to packet collisions and, as a result, packet loss before significant buffer queue building. This circumstance is aggravated by an increase in network users. Congestion control is a vital and essential aspect of the present research issue in communication networks. Several recent reviews in the literature indicate that the congestion issue in the CRN has not been thoroughly studied. Thus, effective and efficient congestion control strategies are sought to optimize network resource usage and management. To prevent congestion, it is crucial for CRN to do research on the creation of an efficient congestion management system. This will improve the network's resource consumption and performance. "Performance improvement via efficient spectrum management through optimum resource management and congestion control in the CRN by mitigating different threats" is the primary target of this project. This research also focused on enhancing performance by addressing security issues in an IoT-based CRN environment. This study provides a comprehensive review of several similar studies and their limitations, which may be used to formulate a new research target.

Keywords: Cognitive Radio Network, Primary Users, Secondary Users, Performance enhancement, Security problems, Resource management, Internet of Things, CRN attacks.

## 1. INTRODUCTION

The CRN is a valuable technology for future generations with the capacity to properly use the spectrum [1]. Due to its effective utilization of the radio frequency spectrum, the CRN has recently acquired appeal in the scientific community. The CR is frequently described as a collection of primary and secondary networks [2]. The primary advantage of CR is that it uses reutilized spectrum resources based on configurability and intelligent sensing. The wireless CRN is used for the concurrent communication of several users on a shared frequency band. Moreover, the cognitive ratio is a dynamically configurable and programmable intellectual ratio [3]. Cognitive radio provides a conscious radio frequency (RF) environment and, as a result, optimizes its operating parameters for SDR systems. Cognitive radio expands the concepts of software-defined radio (SDR) and hardware radio from a device with a specific purpose to a radio that perceives and reacts to its operating environment [4]. Therefore, the ratio that automatically predicts the channels in the wireless spectrum adjusts its reception or transmission characteristics to permit many concurrent wireless communications inside a specific frequency band [5]. Cognitive radio is a means to automatically exploit neighbouring unutilized spectrum to provide exclusive spectrum access routes. "Cross borders and self-adjust to remain in compliance with local restrictions." Negotiate with multiple service providers to connect a user at the lowest possible cost. "Adjust themselves in addition to the releasing the procedure without user intervention." understand and monitor the actions and decisions made by their users, which has taught them to be more responsive and to anticipate their requirements. Cognitive radio technologies may enhance IoT-based cellular networks of the next generation, such as WiMAX and LTE [6], in order to dynamically use these newly available spectrums. The spectrum coordinator adds the non-access stratum (NAS) to allow IoT-based cellular networks to dynamically charter spectrum from spectrum markets and to identify secondary license-exempt spectrum possibilities to satisfy cellular traffic requests depending on location and time. The base stations (including relay stations) [7] create the operating channels based on the instructions of the spectrum aggregate and spectrum coordinator. Figure 1 depicts the cellular network of the CR structure. Users of CR may communicate with one another through contact with the base station or multihop [8].

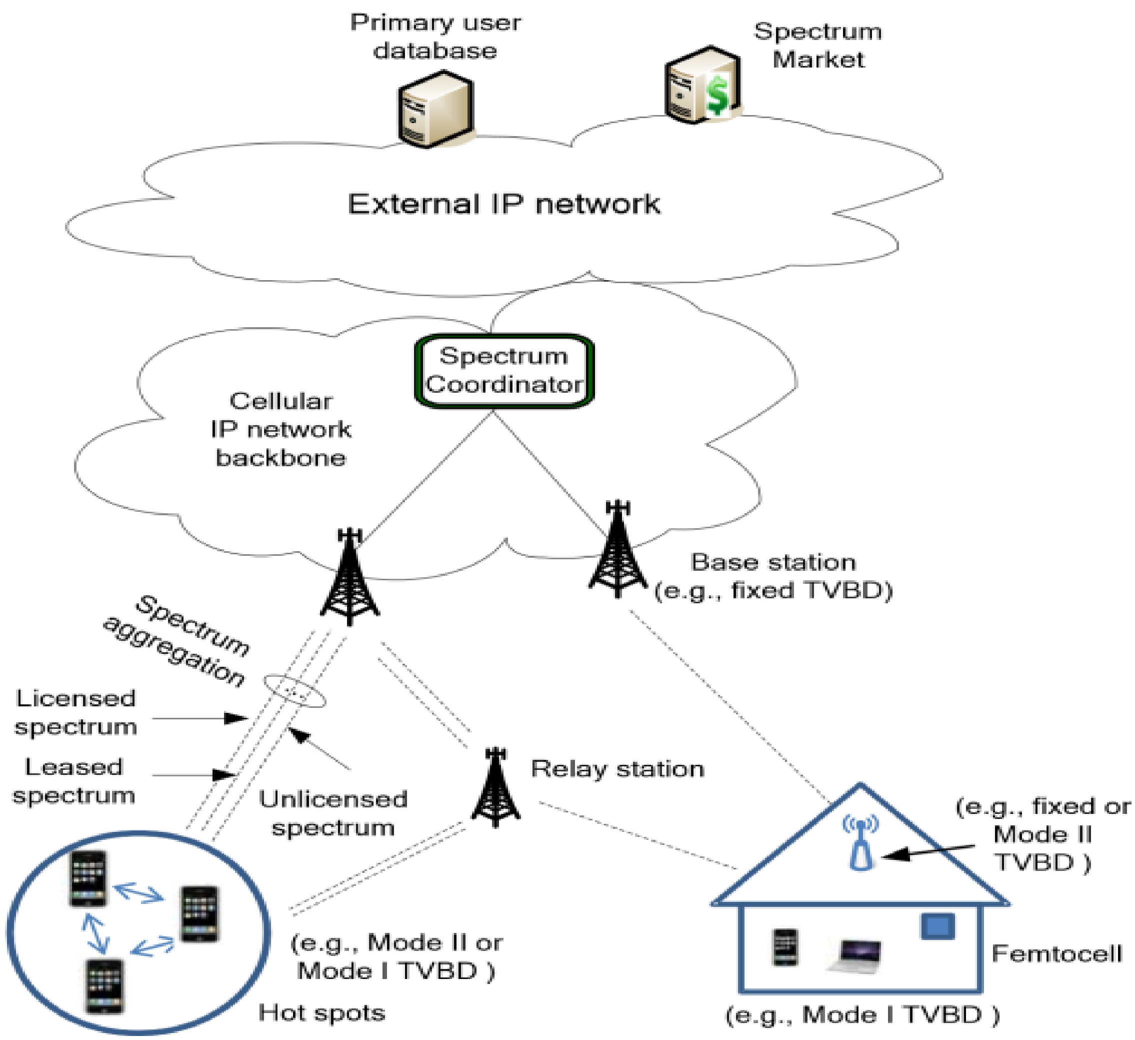


**Figure 1:** IoT based cellular networks in CRN.

## 2. ARCHITECTURE OF COGNITIVE RADIO NETWORK

Figure 2 depicts the fundamental idea of the CR network, as well as its routing architecture, network layer protocols, flexible MAC layer, and physical adaptation. The expansion of CRNs focuses mostly on advancing communication technologies [9]. Multiple users interacting concurrently over a common frequency utilize wireless CRNs. It is also used to reduce the interference between licensed PUs and SUs operating in the same frequency band. The physical layer, media access layer, and network layer are considered under the communication hierarchical architecture scheme [10]. The CRN uses the same frequency spectrum as the most current communication method. The channel estimation procedure is used to estimate the channel capacity and gather information about the channel condition (CSI). Adaptive cognitive radio systems that operate in surroundings that are in a constant state of flux [11] need, in any form, appropriate channel state estimation methods. Estimation of the channel's state is essential for determining the channel's capacity, which in turn is required to aid the transmitter in assessing its candidate operating configuration. Specifically, the cognitive receiver uses the CSI to calculate the feasible bit rate [12] using a well-known theoretical method (such as Shannon's theorem). The services are essential to ensure that networks are able to manage the enormous volume of network optimization data traffic generated by this user activity while preserving service quality and customer satisfaction [13]. It encompasses technology rollout, network transformation, and network optimization to provide an ideal end-user experience and operator profitability [14]. Various algorithms are employed to analyze the network status for greater precision and user satisfaction.

### 2.1. Security in CRN

Within CRNs, the Base stations (BSs) should ensure the availability of the spectrum needed by PUs and SUs. BSs should be equipped with the needed security measures against DoS attacks [15], including distributed DoS.

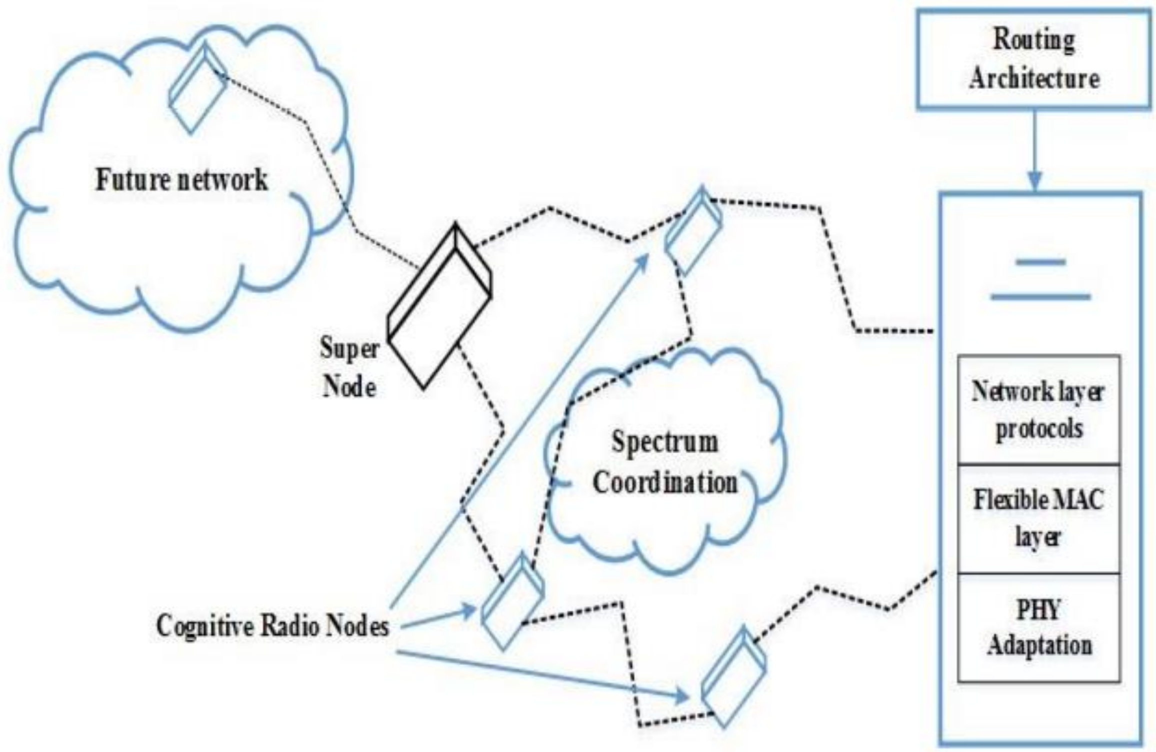


**Figure 2:** Architecture of Cognitive Radio Network

Authentication: To ensure that CRN devices and components are communicating with a legal party, PUs, SUs, and other devices, authenticating them is essential. This applies to BS authenticating CRNs and CRNs authenticating each other. All components involved in the CRNs must be able to identify other legitimate devices and systems. Various cryptographic techniques [16] are used for this purpose. CRNs should be capable of preventing or at least detecting various attacks on cryptographic protocols including man-in-the-middle attacks.

Integrity: It is demanded to ensure that the messages sent by BS, CRN, PU, or SU have not been modified when arriving at their destination. This assurance entitles that the messages received have not been through any modification, insertion, deletion, or replay on its way to its destination. Commands and signals issued by various constituents of the CRN are critical messages, and therefore, need to be clear of any modifications [17]. Cryptographic hash functions and MACS need to be adopted to ensure message integrity.

Confidentiality/Privacy: PUs and SUs are interested in keeping their communications confidential. They want to ensure that their messages are only disclosed to the authorized CRNs, PUs, and SUs. In many applications, such as healthcare applications, privacy is essential. CRNs should adopt cryptology to enforce privacy [18].

Nonrepudiation: Communicating parties in the CRN infrastructure do not want the receiver to deny receiving a message (destination nonrepudiation), and the sender to deny sending a message (source destination). Cryptology can be deployed to ensure, for example, that a CRN cannot deny it has received a request for a spectrum from PUs and SUs, and a CRN cannot deny a message received from a BS [19].

## 3. LITERATURE SURVEY

In [20],the authors implemented two-channel selection strategies to improve the efficiency for the utilization of the SU. For transmission within the service time, the SU chooses the lowest busy channel via historical licensed spectrum information's. The busy nearby licensed spectrum was forecasted and the recursive least square for distance factor was presented for the time series prediction. During the transmission of data, these proposed strategies were used for the reduction in the switching probabilities and collision of the SU. The probability measurements of channel switching, collision and time limitations were evaluated and proved that this method was resulted in better improvement in the SU performance and in the prediction accuracy. In [21], authors suggested the importance of channel allocation in the CRN, which increased the performance and minimized the interference. The goal of reducing the interference was employed by an adaptive channel assignment. But the design and execution of the above channel assignment were a challenging task caused by the spectrum availability and dynamic network circumstances with different channel sizes and characteristics. In [22], the authors illustrated a disseminated spectrum in CRN which handled the multimedia source data that were formed as a group of communication devices and channel managements for the multimedia sources without using a separate controller. The channels were selected using the flexible structure of MAC which was used for device identification in a group and replacement of channels with current channels when an obligatory was detected in any device in the group. In [23], authors described the identification of the vacant channel bands and the selection of an opportunistic channel for efficient performance. For channel selection, the spectrum decision was the best significant process. The channel selection characteristics and functions were involved in the spectrum decision for ideal channel selection. In which the activities of PU were characterized first, then the channel was selected for the gratification of QoS necessities, and finally the parameters were reconfigured for the selected band communication.

In [24], authors demonstrated the usage of resources in the available channels for terrestrial communications and the need of CR for satellite communications. The satellite-terrestrial communication needs the air interface which causes scarcity of frequency bands. For the hybrid satellite-terrestrial communication, a channel detection algorithm was proposed based on bandwidth or time and a weighted channel sensing was introduced. This technique was related to the convention algorithm and results in better sensing of interferences produced by SU and detected the PU presence in time. In [25],the authors suggested the channel sensing mechanism that detects the PU and spectrum utilizing SU which offers low throughput and sensing time. As Scheme based on particle swarm optimization (PSO) was introduced to progress the throughput and to reduce the sensing time. For the analysis of distribution-based criteria such as optimization time, performance, detection, and gain of SU, a Fast Convergence PSO (FC-PSO) was derived.

In [26], authors illustrated the disadvantage of channel switching results in the reduction of throughput in CRN. Currently, the scheme of primary channel selection alone was suggested for the availability of an unlicensed user. Then a fuzzy-based system was proposed for the selection of opportunistic channels using channel gain estimation and the primary users were integrated with Signal-to-Interference-plus-Noise Ratio. In [27], authors illustrated the RF energy harvesting for secondary users in the CRN. In this work, the performance of channel access by secondary users for packet transmission or the RF energy harvesting for the selection of idle channel or occupied primary users were considered. Moreover, the channel access optimizations for secondary users were presented to develop the throughput. For both cases the secondary user should know the current position of the channel [28]. If it was known, the channel probability also should be known. This proposed work involved the optimization of the restrictions such as probability of idle channel, successful packet transmission, and RF energy harvesting. In [29], authors discussed the features of the technologies used in CR such as sensing ability of the operations in devices and real-time adaptation. As a result, CR devices were capable to detecting and accessing the available unused channel bands without any interference. An efficient key mechanism of channel allocation for the cognitive network was presented. The main purpose of the channel assignment was to avoid the interference and to improve its performance.

In [30], authors discussed the improvements in channel utilization and network performance in CRN. The implementation of an innovative Dynamic Channel Selection (DCS) algorithm was proposed for the Wi-Fi cell networks. This algorithm continuously monitored and identified the sources of Wi-Fi cells. Then the operation of the network was configured and the channels were updated. The execution of the algorithm was appraised using the robustness and spectrum efficiency. In [31], authors reviewed the current topics used for the best channel selection in a cognitive radio networks. The initial method used for channel selection was the dynamic channel access in which various strategies were categorized for ideal channel selection. This dynamic access consists of three main models such as Dynamic exclusive model, hierarchical access model, and open sharing model. In [32], authors investigated the routing performance of network characteristics called Cognitive Radio Q-routing, in which the Reinforcement Learning (RL) approach was applied. The considerations of unpredictability and dynamicity and finding the lease cost destination routes were determined using CRQ routing. In [33], the authors offered a scheduling and routing mechanism for various topologies in cognitive radio sensor networks. The scheduling algorithms liable to the channel allocation and time slots for triangle, square, and hexagon topologies were implemented in this projected method. Moreover, the routing mechanisms for these topologies were presented for delay minimization and load balance.

In [34], the authors presented a well-organized coordination of data flow and an energy conservation-based traffic-aware scheme that combines the energy efficient routing protocol. This scheme was used for attaining the best energy conservation and reducing uncontrolled energy consumption by determining the duration of an active node using traffic instants during the sleep time. The operation of an effective routing protocol involves establishing the possible maximum routing paths, maximum energy conservation and minimum delay and signaling mechanism utilization for the progress of secondary communication nodes. In [35], the authors illustrated the description of the routing protocol which has the main characteristics of routing metrics for the ideal route selection in transmission process. In [36], the authors proposed a capability aware scheme with assigning mechanism in the routing protocols of the ad hoc CRN. This proposed mechanism was used for determining the effective routing paths in an architecture that was designed in the simulation scenario basis. The goal of this routing mechanism was to obtain high throughput, efficient selection of routing paths, and optimization of the network. A Backward Traffic Difference (BTD) approach [37] was used for the estimation of energy efficient methods. This proposed scheme utilizes the sleep-wake schedule assignments that liable to the various traffics received in the network.

In [38], authors suggested the importance of routing and its challenges such as dynamicity and interference in CRNS. The minimization of the PUs interferences was the main objective of the routing in the CRNs. A cluster-based routing algorithm called Spectrum-Aware cluster-based Routing (SMART) was introduced in this proposed work. The SUs was formed into groups in this mechanism and the target route nodes were investigated subsequently. In [39], the authors presented a location-based routing protocol with which the desirable properties of the CRN were obtained. In this proposed work, LAUNCH routing protocol was presented for determining the characteristics of CRN like routing stability, mobility of SUs, PUs heterogeneity, efficient channel usage, and minimal routing delay. In [40], the authors presented a location-based routing protocol with which the desirable properties of the CRN were obtained. In this proposed work, LAUNCH routing protocol was presented for determining the characteristics of CRN like routing stability, mobility of SUs, PUs heterogeneity, efficient channel usage, and minimal routing delay [41].The process of smooth fictitious play helped in learning the policies of best response in which the behavioral and local utility information convergences were guaranteed.

In [42], the authors introduced a routing mechanism for the coordination of competent data flow and the conservation of energy in the distributed CRN. The operation of this proposed routing mechanism utilized the evaluation of backward traffic activity for obtaining the traffic manipulation and maximum conservation of energy that were developed using simulations which had numerous secondary nodes operated under the policy of “spectrum of commons” in television white spaces (TVWS). In [43], authors elaborated the manipulation of the routing scheme accompanied with traffic moments that were also aimed at the energy conservation and resource management of the network. The data flow coordination aids the achievement of energy saving and the manipulation of channel access by the exchange of resources between the secondary nodes. The suggested routing mechanism correlated the traffic moments in the backward differences [44] with the sleep-time duration, which minimized the activity time duration for the achievement of energy conservation. By exploiting the adoption of the signaling mechanism, the operation of the recommended routing scheme was achieved. In [45], the authors suggested a hybrid routing mechanism based on clustering with the distribution of non-uniform nodes in the ad hoc network. In this proposed mechanism, the channel nodes were clustered with three main criteria such as node stability, node power level, and channel availability [46]. The occurrences of re-clustering were avoided by forming highly stable clusters and then the delay was minimized by introducing the routing mechanism. This routing mechanism joins the various routing metrics into a global metric for optimization.

In [47], authors addressed the routing process as the most difficult problem in the cognitive radio adhoc network. A Self Adaptive Routing (SAR) mechanism was proposed for ad hoc networks in the multi-hop cognitive radio. In this proposed routing mechanism, an adaptive control mechanism for the range of transmission and routing metrics were integrated for providing self-adaptively. In [48], the authors stated a novel routing mechanism that produced an efficient coordination of data flow and the conservation of energy in the distributed CRN. The operation of the suggested routing mechanism is considered the implementation of energy efficient scheme and signaling mechanisms [49] for obtaining the criteria such as minimum delay, maximum energy conservation, and the establishment of maximum possible routing paths. In [50], authors described the requirements of energy management in a smart grid to be aided a reliable, efficient, and robust routing mechanism in cognitive radio sensor networks (CRSNs). These CRSN based smart grid had applications like the awareness of wide area situation, monitoring, the transmission overhead, demand response, energy management, automation of substation, advanced infrastructure, service management, and outage management.

In [51], the authors mentioned an increased requirement of channel efficient, energy efficient, and resource constrained protocols when there was an increase in node number of the network. For these requirements, the cognitive radio network was combined with the sensor networks, which was called as cognitive radio sensor network. A novel Cognitive Networking with Opportunistic Routing Protocol (CNOR) for WSN was proposed. In [52], the authors proposed a model of trust-based secure routing mechanism for selective forwarding routing attacks in CRN. For mischievous nodes identification, the node trusts were constructed by detecting the forwarding actions of the nodes. Then the collaboration of the selection-based routing model and channel allocation were considered for sending the piggybacking route request for non-mischievous nodes. In [53], the authors stated that the collaboration of nodes became a large challenging issue in the cognitive wireless network. A novel algorithm for collaborative routing in multi-hops cognitive networks was constructed in this proposed work. In this algorithm [54], the interferences from the primary and secondary users were deliberated. The performance of the suggested collaborative routing mechanism was improved by manipulating the collaboration and clustering of wireless networks with multiple users.

In [55], the authors introduced a MAC protocol identification for the extraction of features using machine learning algorithms in the cognitive radio network. This cognitive MAC protocol has the capability of sensing and identifying various protocols. In this proposed work, the features of time and power in the network were extracted and the types of the MAC protocol such as CSMA/CA, TDMA, pure ALOHA, and slotted ALOHA were recognized using the machine learning algorithm like Support Vector Machine. In [56], the authors suggested an improved cooperative spectrum sensing (CSS) algorithm based on the machine learning mechanism in CRN. This spectrum sensing algorithm involves two major steps such as the K-means clustering [57] method for online training and classification results with the threshold. First, availability decision of the channel was done by exploiting the similarities of the cluster and the received signal and the extraction of resulted features were done by Principle Component Analysis (PCA). In [58], authors illustrated the use of a reliable modulation classification (MC) scheme for spectrum sensing. This work proposed a feature clustering algorithm on the time and frequency distribution. This proposed algorithm used a Pseudo Wigner-Ville Distribution (PWVD) approach for feature extraction, and the Density-Based Spatial Clustering of Applications with Noise (DBSCAN) [59] was used for the taxonomy of single carrier modulation.

In [60], authors discussed the spectrum detection as a main operation in CR where the channel corruptions by SUs identify the PUs presence. This accurate detection was achieved by CSS that exploits the SUs spatial diversity and it was based on the energy sensing in which the performance under noise or intrusion were not satisfied [61]. So, a kernel-based canonical correlation analysis (KCCA) scheme was proposed to perform the operations under non ideal and blind fashion scenarios. In [62], authors defined the channel availability in which the chances of unlicensed users communicating with the available licensed channel. This was the main parameter used for the channel selection design and routing metrics in CRN. This channel availability was determined liable to the activity of the primary users in the static scenarios. But in movable scenarios, the channel availability was varied dynamically [63] with time due to the changes in the position of users. Hence, the features of the channels in the movable scenario were extracted using the policy of channel availability approximation in this proposed work. In [64], the authors proved that the spectrum sensing schemes liable to features were desirable in the case of low SNR conditions. This cyclo-stationary feature-based scheme compared the signal feature values with a predefined threshold value for detecting the existence of primary signals, which resulted in the deterioration of the performance due to the influence of noise in the features. This proposed scheme implemented the sparse decomposition technique [65] and low rank for cyclo-stationary -based sensing. The matrix of spectrum correlation function could be disintegrated into two matrices, in which the low rank matrix denotes the interference and noise, whereas the sparse technique denotes the cyclo-stationary features of PU signal.

In [66], the authors focused on the progress in the performance detection of spectrum sensing under problematical electromagnetic environment. Some of the present spectrum detection algorithms might be failed to detect the features of the signals that were provided by the licensed users and the feature. In [67], authors illustrated the efficient sensing of available frequency bands in the cognitive radio. For that, a well-organized architecture was implemented in the CRN. This work implemented a stable cluster-based architecture for ad hoc networks in which the network was splitted into a group of clusters that considered the available spectrum spatial variations [68]. A group of free channels in every cluster was resided for shifting the control channels smoothly. In this proposed architecture, the cluster heads were collected using the parameter called Cluster Head Determination Factor (CHDF) and the operation of the clusters was coordinated by cluster heads. Then the secondary cluster heads were comprised for the conflict of reclustering issues. In [69],the authors considered broadcasting as the main operation in cognitive radio networks which aimed at the enhancement of utilization of spectrum. Liable to the control information of broadcast from the neighborhood nodes, the adhoc network protocols were operated. For traditional networks like single or multichannel adhoc networks [70], the broadcasting was implemented easily because of its availability of the channel in a uniform manner. But for CR adhoc networks, the implementation and operation of the broadcasting became a difficult task. The main challenge was the user acquirement of different channels at various times, which divided the network into various clusters. In [71], authors illustrated the study of various machine learning algorithms like Artificial Neural Network (ANN), SVM, k-nearest neighbor (KNN), random forest tree, Hoeffding tree and Naïve Bayes method for Automatic modulation recognition (AMR). Particularly, a Nonnegative Matrix Factorization (NMF) technique [72] was presented in this proposed work and the comparative results were evaluated using the mentioned traditional techniques.

In [73] authors illustrated the drawbacks like high computational complexity, degradation in accuracy, and low detection rate that aroused using the traditional channel detecting techniques. This work suggested a new technique of fast spectrum detection with coordination system (FSC) in order to achieve a high detection rate and low sensing time. This proposed technique provided better buffer space and fast sensing process in the recognition of PU. In [74], authors compared the analysis of two sensing techniques such as multiple energy detector (MED) and cyclo-stationary feature detector. This channel sensing technique solved the complication of channel scarcity. The proposed MED technique used Adaptive Double Threshold scheme for sensing the available channel [75]. In this proposed model, each energy detector has an antenna that provides improvement in the system reliability, bit error rate, reduction in shadowing and multipath effects, and the fast process [76]. This model assumed the selection combiner (SC) which has channel estimation overhead and complexity. In [77], authors encountered the necessity of the channel and its utilization importance in the ad hoc cognitive radio network. The channel was divided into overlapping orthogonal channels and the available channels were sensed by detecting the PUs using detection methods such as energy detectors [78], Eigen value-based feature extraction, and feature extraction. The operation of the proposed clustering-based architecture was evaluated using Semi-Markov ON-OFF model. In [79], authors analyzed the channel sensing problem due to the domain of angle using the estimation of Angle of Arrival (AoA). The spatial spectrum property of noise has the central symmetry feature which does not havean arriving signal. The features of the central symmetry were existed with the existence of pus [80]. Here, a blind central symmetry-based feature detection (CSIF) method was presented by introducing a framework of spatial spectrum sensing. The spatial spectrum was evaluated by the estimation of AoA, which was much more different under the existence or nonexistence of PUs.

## 4. PROBLEM STATEMENT

### 4.1. Problem statement based on resource management

CR technology brings revolution and is expected to dominate the field of communication in the near future. To study the dynamic behavior of CRN properly, the effect of non-stationary conditions must be considered for the evaluation of performance. One of the most important and key concerns of CRN is guaranteed reliable communication. Efficient and safe exchange of information is necessary not only for the accomplishment of the task but for network security and lifetime too. Each SU needs to achieve the mission of flawless transmission objectives while maintaining minimum resource consumption. The communication becomes complicated and challenging when SU bandwidth for data transmission changes. More efficient and reliable communication solutions are required with an increase in the number of SUs. The key issues in the communication problems of CRN are listed below:

Traffic: In CRN, different priority class traffic has different requirements for QoS. Network complexity also increases as shared resources are used by mixed (PU and SU) traffic. As the data packets arrivals are typically burst in nature, the non-stationary traffic loads leads to the time-varying behavior of PU and SU traffic queues in the shared network. This feature increases with increase in the scale of network.

Congestion: As communication resources like channel capacity are limited, the network QoS degrades with resource saturation. To avoid congestion problems, the network takes a set of actions to minimize the intensity, duration, and spread of network congestion. In this case, congestions need to be avoided by appropriate management of network resources and regulating the traffic flow in the network.

Bandwidth Constraints: The dynamics of data packet arrival are different for SU and PU. Consequently, their bandwidths are accordingly allocated. As the SU dynamics are subject to spectrum mobility. Therefore, for maximum utilization, the management of bandwidth should be dynamic and adaptable to changes. Resource management is widely recognized as one of the prime concerns in CRNs. Several efforts are made in order to achieve the fairness of bandwidth management which is related to the solution of congestion.

Power Consumption: Communications among the nodes are strongly dominated by energy and power consumption in addition to other functionalities such as sensing and processing. Packets are discarded when it gets corrupted and are followed by packet retransmissions. This increases the possibility of congestion and results in more power and energy consumption. Therefore, to develop new concepts for congestion control embedded with low power requirements and regulating energy consumption in SUs are needed.

### 4.2. Problem statement based on network security

In wireless communication, the data transmission is based on the coverage range of the cell structure. The bandwidth (BW) range is maximized to acquire high coverage area and to perform continuous data transmission. This may outcome in increasing of the BW losses that are not in usage, Static variation in BW usage that leads to data loss, Minimizes the data transmission rate CRN is susceptible to various attacks.

These issues motivate this work to avoid the above limitations, CRN is formed to switch the network link during communication with dynamic bandwidth modulation and develop a highly efficient security measure against the attacks. CR predicts the better channel usage made to interconnect in the particular link.

## 5. FUTURE OBJECTIVES

The main objectives of this thesis are as follows

To construct a game theory model for computation of available resources in the IoT network

To minimize the system delay and to optimize the spectrum band range, the time slot-based routing algorithm is used.

To enhance the channel selection framework for optimal routing, a novel deep learning model will be introduced.

To transfer the data from one node to another node, the time slot consumption is minimized by using an optimized routing algorithm.

To develop an efficient security mechanism against attacks, the beam forming based optimal feature extraction technique will proposed.

To classify whether the communication nodes as an attacker or normal, the deep transfer learning-based classification technique is utilized.

## 6. CONCLUSION

For passive eavesdropping, attacks, messages need to be encrypted and time stamped and nonce added to prevent replays. PUs and SUs will verify the message and only accept it if it is verifiable. To prevent impersonation attacks, anonymous IDs are recommended. The BS or CRN node will issue anonymous IDs for all PUs and SUs. These anonymous IDs will be changed at the same time the encryption key is changed. Even if this anonymous ID is captured, the attacker will not know whose ID it is to impersonate. To counter the attack selective forwarding attack, the CR node or BS can establish a timing limit. If this limit is exceeded and the PU or SU has not received the message, it will inform the BS through another secure node. The BS will then resend the message using that route or another one if needed. Certainly, the messages must be encrypted so that the malicious CR will not extract any useful information from the message. To prevent an attacker from actually providing a false high-quality route to a sink in case cognitive sensor networks are used, CR nodes can request certificates. These certificates could be issued by BS or by a Cognitive Radio Network Authority. In addition, CR nodes can forward the info about that high-quality sink to the BS for verification.

To thwart the possibility of a single CR node pretending to be present at different locations of the network (Sybil attack), anonymous IDs need to be used and changed frequently. In addition, requiring certificates is necessary to further counter measure this attack. To counter measure the possibility of wormholes, the BS must provide each node with the anonymous IDs of the neighboring nodes and the distances from each one of these nodes. All this information must be encrypted. Any wormhole trying to convince two distant CR nodes that they are neighbors will fail when they check their list of anonymous IDs and distances to verify that claim. For Hello Flood attack, certificates and authentication need to be enforced. Furthermore, routing protocols that use link layer acknowledgments must be replaced by more secure protocols. To account for hardware attacks, hardware encryption must be provided. This prevents attackers from accessing the hardware of the node, and consequently will not be able to shut down a CR node. To resist software attacks, tamper-resistance, intrusion detection systems, and virus detection techniques should be incorporated to deter any malicious software installations. Dealing with the primary user emulation attacks is not easy. However, the most important characteristics could be hashed or digitally signed. Therefore, the destination node will verify these characteristics first before responding. This can apply to the signal too. Jammers transmit a signal to the receiving antenna of the CR with the same frequency as that of an authorized transmitter. CRs should check IDs, certificates, and possibly authenticate the transmitting node whenever a signal with the same frequency is received. Byzantine attack should be mitigated with enforced authentication schemes between the sensing SUs and the fusion center. The fusion center must verify any sensing information received from CR nodes in order to assess their integrity. Authenticating CR nodes can avoid receiving and using misleading information about PU activities, which can be disseminated by malicious nodes.In case of completely distributed and cooperative sensing, PKI schemes should be established to manage identity verification.

## 7. REFERENCES


[1] Nallarasan, V., and K. Kottilingam. "Spectrum management analysis for cognitive radio IoT." 2021 international conference on computer communication and informatics (ICCCI). IEEE, 2021.

[2] Nurelmadina, Nahla, et al. "A systematic review on cognitive radio in low power wide area network for industrial IoT applications." Sustainability 13.1 (2021): 338.

[3] Nasser, Abbass, et al. "Spectrum sensing for cognitive radio: Recent advances and future challenge." Sensors 21.7 (2021): 2408.

[4] Long, Nguyen Quoc, et al. "Physical layer security in cognitive radio networks for IoT using UAV with reconfigurable intelligent surfaces." 2021 18th International Joint Conference on Computer Science and Software Engineering (JCSSE). IEEE, 2021.

[5] Khaf, Sadia, Mohammad T. Alkhodary, and Georges Kaddoum. "Partially cooperative scalable spectrum sensing in cognitive radio networks under SDF attacks." IEEE Internet of Things Journal (2021).

[6] Prajapat, Rajendra, Ram Narayan Yadav, and Rajiv Misra. "Energy-efficient k-hop clustering in cognitive radio sensor network for Internet of Things." IEEE Internet of Things Journal 8.17 (2021): 13593-13607.

[7] Gul, Omer Melih. "Near-Optimal opportunistic spectrum access in cognitive radio networks in the 5G and IoT Era." 2021 IEEE 46th Conference on Local Computer Networks (LCN). IEEE, 2021.

[8] Asifuddola, Mohd, Roohie Naaz Mir, and Mohammad Ahsan Chishti. "An Optimal Asymmetric Synchronous Blind Rendezvous Algorithm in Cognitive Radio Networks for Internet of Things." Arabian Journal for Science and Engineering (2022): 1-13.

[9] Asifuddola, Mohd, and Mohammad Ahsan Chishti. "A novel fast and fair asynchronous channel hopping rendezvous scheme in cognitive radio networks for internet of things." Journal of Ambient Intelligence and Humanized Computing (2021): 1-13.

[10] Abbas, Ghulam, et al. "Reliability Analysis of Cognitive Radio Networks with Reserved Spectrum for 6G-IoT." IEEE Transactions on Network and Service Management (2022).

[11] Chithaluru, Premkumar, et al. "An enhanced energy-efficient fuzzy-based cognitive radio scheme for IoT." Neural Computing and Applications (2022): 1-23.

[12] Darabkh, Khalid A., et al. "Yet efficient routing protocols for half-and full-duplex cognitive radio Ad-Hoc Networks over IoT environment." Journal of Network and Computer Applications 173 (2021): 102836.

[13] Miah, Md Sipon, Michael Schukat, and Enda Barrett. "A throughput analysis of an energy-efficient spectrum sensing scheme for the cognitive radio-based Internet of things." EURASIP Journal on Wireless Communications and Networking 2021.1 (2021): 1-36.

[14] Nallarasan, V., and Kottilingam Kottursamy. "Cognitive radio jamming attack detection using an autoencoder for CRIoT network." Wireless Personal Communications (2021): 1-17.

[15] Majumder, Saikat, and Mukhdeep Singh Manshahia. "Optimal Quantizer and Machine Learning–Based Decision Fusion for Cooperative Spectrum Sensing in IoT Cognitive Radio Network." Handbook of Intelligent Computing and Optimization for Sustainable Development (2022): 605-636.

[16] Majumder, Saikat, and Mukhdeep Singh Manshahia. "Optimal Quantizer and Machine Learning–Based Decision Fusion for Cooperative Spectrum Sensing in IoT Cognitive Radio Network." Handbook of Intelligent Computing and Optimization for Sustainable Development (2022): 605-636.

[17] Ahmed, Ramsha, et al. "CR-IoTNet: Machine learning based joint spectrum sensing and allocation for cognitive radio enabled IoT cellular networks." Ad Hoc Networks 112 (2021): 102390.

[18] Gopikrishnan, S., P. Priakanth, and Gautam Srivastava. "DEDC: Sustainable data communication for cognitive radio sensors in the Internet of Things." Sustainable Computing: Informatics and Systems 29 (2021): 100471.

[19] Siddikov, Ilkhom, et al. "CRN and 5G based IoT: Applications, Challenges and Opportunities." 2021 International Conference on Information Science and Communications Technologies (ICISCT). IEEE, 2021.

[20] Abdalzaher, Mohamed S., et al. "A deep autoencoder trust model for mitigating jamming attack in IoT assisted by cognitive radio." IEEE Systems Journal (2021).

[21] Tan, Xiang, et al. "Cooperative multi-agent reinforcement learning based distributed dynamic spectrum access in cognitive radio networks." IEEE Internet of Things Journal (2022).

[22] Jothiraj, Sivasankari, Sridevi Balu, and Neelaveni Rangaraj. "A hybrid-supervised learning model for compressive spectrum sensing in fifth generation (5G) cognitive Radio enabled internet of things (IoT) networks." International Journal of Communication Systems 34.9 (2021): e4797.

[23] Benmammar, Badr. "Internet of things and cognitive radio: Motivations and challenges." International Journal of Organizational and Collective Intelligence (IJOCI) 11.1 (2021): 39-52.

[24] Bala, Indu, et al. "Throughput optimization of interference limited cognitive radio-based internet of things (CR-IoT) network." Journal of King Saud University-Computer and Information Sciences (2022).

[25] Amini, Mohammad Reza, and Mohammed W. Baidas. "Performance analysis of URLL energy-harvesting cognitive-radio IoT networks with short packet and diversity transmissions." IEEE Access 9 (2021): 79293-79306.

[26] Ghasemzadeh, Pejman, Michael Hempel, and Hamid Sharif. "GS-QRNN: A High-Efficiency Automatic Modulation Classifier for Cognitive Radio IoT." IEEE Internet of Things Journal (2022).

[27] Leena, K., and S. G. Hiremath. "Cognitive Radio Networks for Internet of Things." Intelligent Sustainable Systems. Springer, Singapore, 2022. 515-526.

[28] Alnabelsi, Sharhabeel H., et al. "A multi-layer hyper-graph routing with jamming-awareness for improved throughput in full-duplex cognitive radio networks." Journal of King Saud University-Computer and Information Sciences (2022).

[29] Latif, S., Akraam, S., Karamat, T., Khan, M. A., Altrjman, C., Mey, S., & Nam, Y. (2022). An Efficient Pareto Optimal Resource Allocation Scheme in Cognitive Radio-Based Internet of Things Networks. Sensors, 22(2), 451.

[30] Aslam, M. M., Du, L., Zhang, X., Chen, Y., Ahmed, Z., & Qureshi, B. (2021). Sixth generation (6G) cognitive radio network (CRN) application, requirements, security issues, and key challenges. Wireless Communications and Mobile Computing, 2021.

[31] Das, K., & Banerjee, J. S. (2022). Cognitive Radio-Enabled Internet of Things (CR-IoT): An Integrated Approach towards Smarter World. In Applications of Machine Intelligence in Engineering (pp. 541-555). CRC Press.

[32] Jaronde, Pravin W., Archana Vyas, and Mahendra Gaikwad. "A Survey on Energy Aware Cognitive Radio Network." 2022 2nd International Conference on Power Electronics & IoT Applications in Renewable Energy and its Control (PARC). IEEE, 2022.

[33] Maharaj, Bodhaswar TJ, and Babatunde Seun Awoyemi. "The Role of Cognitive Radio Networks in Fifth-Generation Communication and Beyond." Developments in Cognitive Radio Networks. Springer, Cham, 2022. 209-217.

[34] Teekaraman, Y., & Manoharan, H. (2021). Implementation of Cognitive Radio Model for Agricultural Applications using Hybrid Algorithms. Wireless Personal Communications, 1-18.

[35] Mukherjee, A., Li, M., Goswami, P., Yang, L., Garg, S., & Piran, M. (2021). Hybrid NN-based green cognitive radio sensor networks for next-generation IoT. Neural Computing and Applications, 1-9.

[36] He, Tengjiao, et al. "A novel distributed resource allocation scheme for wireless-powered cognitive radio Internet of Things networks." IEEE Internet of Things Journal 8.20 (2021): 15486-15499.

[37] Idrees, Zeba, et al. "Fast and Robust Spectrum Sensing for Cognitive Radio Enabled IoT." IEEE Access 9 (2021): 165996-166007.

[38] Salika, Firas, et al. "LoRaCog: A Protocol for Cognitive Radio-Based LoRa Network." Sensors 22.10 (2022): 3885.

[39] Miah, Md Sipon, et al. "Machine learning-based malicious user detection in energy harvested cognitive radio-internet of things." (2021).

[40] Alvi, Shakeel A., et al. "QoS-oriented optimal relay selection in cognitive radio networks." Wireless Communications and Mobile Computing 2021 (2021).

[41] Yogita, Thareja, Kamal Kumar Sharma, and Parulpreet Singh. "Cognitive Radio Networks: A Merit for Teleforensics." Digital Forensics and Internet of Things: Impact and Challenges (2022): 211-225.

[42] Asifuddola, Mohd, and Mohammad Ahsan Chishti. "Quality of service aware channel hopping rendezvous in cognitive radio networks for Internet of Things." International Journal of Computing and Digital Systems 10.1 (2021): 265-276.

[43] Hasan, M. K., Chowdhury, M., Monwar, J., Ahmed, S., Sabuj, S. R., Nibhen, J., & Bakar, K. A. (2021). Optimum energy harvesting model for bidirectional cognitive radio networks. EURASIP Journal on Wireless Communications and Networking, 2021(1), 1-23.

[44] Shakhov, Vladimir, and Insoo Koo. "An efficient clustering protocol for cognitive radio sensor networks." Electronics 10.1 (2021): 84.

[45] Shakhov, Vladimir, and Insoo Koo. "An efficient clustering protocol for cognitive radio sensor networks." Electronics 10.1 (2021): 84.

[46] Paul, Anal, and Santi Prasad Maity. "Reinforcement Learning Based Q-Routing: Performance Evaluation on Cognitive Radio Network Topologies." Wireless Personal Communications (2022): 1-17.

[47] Giang, Hoang Thi Huong, Pham Duy Thanh, and Insoo Koo. "Deep Q-learning-based resource allocation for solar-powered users in cognitive radio networks." ICT Express 7.1 (2021): 49-59.

[48] Rai, Prativa, M. K. Ghose, and Hiren Kumar Deva Sarma. "Game theory based node clustering for cognitive radio wireless sensor networks." Egyptian Informatics Journal (2022).

[49] Shakhov, Vladimir, and Insoo Koo. "Analysis of a Network Stability-Aware Clustering Protocol for Cognitive Radio Sensor Networks." IEEE Internet of Things Journal 8.15 (2021): 12476-12477.

[50] Ali, Zain, et al. "Fair power allocation in cooperative cognitive systems under NOMA transmission for future IoT networks." Alexandria Engineering Journal 61.1 (2022): 575-583.

[51] Manman, Li, et al. "Distributed artificial intelligence empowered sustainable cognitive radio sensor networks: A smart city on-demand perspective." Sustainable Cities and Society 75 (2021): 103265.

[52] Afzal, Humaira, et al. "Performance analysis of QoS in IoT based cognitive radio Ad Hoc network." Concurrency and Computation: Practice and Experience 33.23 (2021): e5853.

[53] Miao, L., Qing, H., Huo, Z. M., Sun, Z. X., & Di, X. (2022). Genetic algorithm-based hybrid spectrum handoff strategy in cognitive radio-based internet of things. Telecommunication Systems, 1-12.

[54] Deebak, B. D., Al-Turjman, F., & Zahmatkesh, H. (2022). An efficient lightweight privacy-preserving scheme for secondary users in cognitive radio networks. In Sustainable Networks in Smart Grid (pp. 233-253). Academic Press.

[55] Hossain, M. S., & Miah, M. S. (2021). Machine learning-based malicious user detection for reliable cooperative radio spectrum sensing in Cognitive Radio-Internet of Things. Machine Learning with Applications, 5, 100052.

[56] Gul, O. M., & Kantarci, B. (2022). Near optimal scheduling for opportunistic spectrum access over block fading channels in cognitive radio assisted vehicular network. Vehicular Communications, 37, 100500.

[57] Hossain, M. A., Schukat, M., & Barrett, E. (2021, January). A reliable energy and spectral efficient spectrum sensing approach for cognitive radio based IoT networks. In 2021 IEEE 11th Annual Computing and Communication Workshop and Conference (CCWC) (pp. 1569-1576). IEEE.

[58] Fang, Y., Li, L., Li, Y., & Peng, H. (2021, October). High Efficient and Secure Chaos-Based Compressed Spectrum Sensing in Cognitive Radio IoT Network. In 2021 IEEE Sixth International Conference on Data Science in Cyberspace (DSC) (pp. 670-676). IEEE.

[59] Srivastava, V., & Singh, P. (2022). Review on a Full-Duplex Cognitive Radio Network Based on Energy Harvesting. In Proceedings of Trends in Electronics and Health Informatics (pp. 587-598). Springer, Singapore.

[60] Liu, Y., Qin, X., Huang, Y., Tang, L., & Fu, J. (2022). Maximizing Energy Efficiency in Hybrid Overlay-Underlay Cognitive Radio Networks Based on Energy Harvesting-Cooperative Spectrum Sensing. Energies, 15(8), 2803.

[61] Miah, Md Sipon, et al. "An energy efficient cooperative spectrum sensing for cognitive radio-internet of things with interference constraints." (2021).

[62] Dhiman, G., & Sharma, R. (2022). SHANN: an IoT and machine-learning-assisted edge cross-layered routing protocol using spotted hyena optimizer. Complex & Intelligent Systems, 8(5), 3779-3787.

[63] Cicioğlu, M., Çalhan, A., & Miah, M. S. An effective routing algorithm for spectrum allocations in cognitive radio based internet of things. Concurrency and Computation: Practice and Experience, e7368.

[64] Tran, T. N., Nguyen, T. V., Shim, K., & An, B. (2021, April). An optimal QoS multicast routing protocol in IoT enabling cognitive radio MANETs: A deep Q-learning approach. In 2021 International Conference on Artificial Intelligence in Information and Communication (ICAIIC) (pp. 279-283). IEEE.

[65] Kumar, A., Pandit, S., Thakur, P., & Singh, G. (2022). Optimization of Fusion Center Parameters With Threshold Selection in Multiple Antenna and Censoring-Based Cognitive Radio Network. IEEE Sensors Journal, 22(5), 4709-4721.

[66] Zhang, J., Liu, M., Zhang, N., Chen, Y., Gong, F., Yang, Q., & Zhao, N. (2021). Reliable Detection of Transmit-Antenna Number for MIMO Systems in Cognitive Radio-Enabled Internet of Things. IEEE Internet of Things Journal.

[67] Dias Santana, G. M., Cristo, R. S. D., & Lucas Jaquie Castelo Branco, K. R. (2021). Integrating cognitive radio with unmanned aerial vehicles: An overview. Sensors, 21(3), 830.

[68] Ge, Yao, and P. C. Ching. "Energy Efficiency for Proactive Eavesdropping in Cooperative Cognitive Radio Networks." IEEE Internet of Things Journal (2022).

[69] Nguyen, Nhan Duc, Anh-Tu Le, and Munyaradzi Munochiveyi. "Secrecy outage probability of reconfigurable intelligent surface-aided cooperative underlay cognitive radio network communications." 2021 22nd Asia-Pacific Network Operations and Management Symposium (APNOMS). IEEE, 2021.

[70] Rajpoot, V., & Tripathi, V. S. (2022). Cross-layer design based hybrid MAC protocol for cognitive radio network. Physical Communication, 50, 101524.

[71] Bennaceur, Jihen, Hanen Idoudi, and Leila Azouz Saidane. "Hierarchical game-based secure data collection with trust and reputation management in the cognitive radio network." Computers & Electrical Engineering 96 (2021): 107463.

[72] Bhatt, R., Onyema, E. M., Almuzaini, K. K., Iwendi, C., Band, S. S., Sharma, T., & Mosavi, A. (2022). Assessment of dynamic swarm heterogeneous clustering in cognitive radio sensor networks. Wireless Communications and Mobile Computing, 2022.

[73] Tan, Y., & Jing, X. (2021). Efficient approximations for optimization of N-out-of-K rule for heterogeneous cognitive radio networks. Applied Sciences, 11(7), 3083.

[74] Yuan, Siyu, et al. "Deep reinforcement learning for resource allocation with network slicing in cognitive radio network." Computer Science and Information Systems 18.3 (2021): 979-999.
[75] Ul Hassan, M., Rehmani, M. H., Rehan, M., & Chen, J. (2022). Differential privacy in cognitive radio networks: A comprehensive survey. Cognitive Computation, 1-36.
[76] Vani, B. P., and R. Sundarguru. "Novel Cognitive Radio Framework for Optimized Resource Management over IoT Ecosystem." 2021 International Conference on Computer Communication and Informatics (ICCCI). IEEE, 2021.
[77] Zheng, Meng, et al. "SACR: A Stability-Aware Cluster-Based Routing Protocol for Cognitive Radio Sensor Networks." IEEE Sensors Journal 21.15 (2021): 17350-17359.

DOI: https://doi.org/10.15379/ijmst.v10i2.3041