Cognitive Radio Networks based Internet of Things: A Survey on Spectrum Sharing or Spectrum Allocation Schemes

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Abstract - *The Internet of Things is a promising subject of technical, social, and economic implication. The first aspect of Internet of Things is different objects are being combined with internet connectivity with powerful data analytic capabilities. Internet of Things paradigm pretense new challenges to the communication technology as several objects of heterogeneous in nature needs to be connected and one among the key challenges is that the scarcity of available spectrum to ascertain the connectivity. To handle these issues, new radio technologies and network architectures can be thought of to accommodate several future devices having connectivity demands and consequently trends are shifting to the network which is intelligent enough to adapt with the environment i.e. Cognitive Radio Networks and its introduction into Internet of Things can improve the efficiency of the spectrum. This paper presents most of the researches addressing channel allocation and packets scheduling, when merging the cognitive radio networks with the Internet of Things technology*.

***Key Words*: Cognitive Radio Network, Internet of Things, spectrum sharing, spectrum allocation.**

1. INTRODUCTION

The Internet of Things (IoT) is the interconnection of physical devices with the Internet and other networks through uniquely identifiable IP addresses, whereby data is gathered and communicated through embedded sensors, electronics and software. The concept of IoT has evolved rapidly in order that it touches most of the everyday life. Due to growing demand of IoTs, a spectrum needs to be allocated for the packets produced from the IoT networks. A concept called "Cognitive Radio Networks (CRNs)" was introduced to be integrated with the IoT concept naming it as "Cognitive Radio Internet of Things (CRIoT)", to allow the IoT access enough spectrum band as required.

The paper addresses spectrum sharing andallocation schemes used in CRIoT. Authors in [1,2] studied different spectrum allocation techniques in CRNs, while authors in [3] explored various spectrum sharing schemes based on biology inspired paradigms describing both social and non-social interactions among agents for dynamic spectrum access. Authors in [4] surveyed spectrum sharing techniques of IoT technologies applied on licensed cellular andunlicensed spectrum band.

2. LITERATURE SURVEY

M. A. Shah and et al. has described about the IoT and CR and their applications [5]. They also discussed the importance of adding cognitive capabilities to IoT devices together with the challenges that might be faced with cognitive radio like security issues, software radio issues, hardware constraints, Wide Band Spectrum Sensing (WBSS) and spectrum sharing. The paper have not discussed about the requirements, standards and practical problems and issues of CR-based IoT. It also failed to specify the way to add the cognitive capabilities to IoT devices.
A. A. Khan et al. [6] have done classification of IoT based on orientation and whether the IoT is wired or wireless. The authors also discussed the spectrum sensing paradigms for CR-based IoT. The paper has also discussed the challenges of adopting CR for IoT. The work failed to discuss the applicable Spectrum Sensing (SS) approaches for various IoT applications. The paper also failed to specify the way to incorporate CR in IoT devices.

Few authors have introduced the demand of adopting CR for IoT applications [7] and have discussed the standardization efforts in CRN-based IoT. The authors have thoroughly described architectures and frameworks of CR-based IoT and focused on CR modules and discussed their functions. They have also discussed different types of spectrum related functionalities in CR based IoT. The authors have presented issues, challenges and future research directions of hardware design for CR-based IoT, spectrum related functions, semantic analysis, networking addresses, standardization activities along with its privacy and security. The work failed to discuss the applicable SS approaches for different IoT applications. The authors did not discuss the applicable spectrum sharing approaches for IoT applications and the way to improve the spectrum efficiency.

The authors have reviewed the principle of SS and spectrum sharing approaches and configurations in [8]. The authors have discussed various applicable spectrum sharing approaches for CR-based IoT systems. The paper also described a general four layer architecture for various spectrum sharing approaches employed by CR-based IoT system. The authors have analyzed security threats and attacks scenarios that might occur during spectrum sharing process. They have also proposed a solution for the attacks. The work failed to discuss the way to select the proper SS approach for a particular IoT application and the selection of MAC protocols for CR-based IoT system.

The unlicensed Industrial, Scientific and Medical (ISM) radio band is the most suitable frequency band for the implementation of IoT services. ISM band is popular because of its flexibility and low cost. It does not impose any limitations on wireless coverage and topology [9,10]. SigFox, Long Range (LoRa) and Wireless Smart Utility Network (Wi-SUN) are different technologies for IoT services that use the unlicensed band within 800-900 MHz [10,11]. Consequently, it has resulted into a congested and overcrowded ISM radio bands and the 800-900MHz band. Cisco has predicted that almost all the wireless technologies like WiFi, ZigBee, WiMAX, Bluetooth Low Energy (LE) and IPv6 over Low Power Wireless Personal Area Network (6LoWPAN) are key enablers for IoT services [12]. These operate in ISM radio band. Thus it becomes necessary to shift the conventional static spectrum allocation policy to dynamic allocation policy to overcome such problems. It implies that the benefits of CR techniques is gained in IoT devices provided these devices fit well together with CRs.

3. INTERNET OF THINGS

IoT is defined as a worldwide network of interconnectedobjects or devices. These devicesare assigned an IP address to be ready to transmit or receive packets over a network. These things can be interconnected either through a wired medium or wireless. Wireless connection is employed frequently because of its flexibility. The desired communication in which the objects will interact together has minimum human intervention [5,6]. IoT devices usually have low: cost, power, battery duration, bit rate, range, storage, processing and less range. IoT networks have simple protocols and more number of connections and [7]. As shown in figure 1, the IoT [8,9,10] has five layered architecture:

1. Perception (also called recognition) layer: It collects the intended information and converts it into data. It represents the physical things, like RFID tags, sensors, actuators, etc.
2. Transmission (also called network) layer: Its main role is to use networking technologies to transfer the information collected by perception layer to the middleware layer or receive control signals from the middleware layer to the perception layer.
3. Middleware layer: It is a software layer that analyzes the received information from the previous layer, and decisions are taken based on the analysis.
4. Application layer: It contains the IoT application and provides services to an end user according to the processed data.
5. Business layer: Its main role is to permit the system administration to control and manage the functionality of the whole IoT networks based on the data received from the previous layer. It builds various business models.

IoT networks are estimated to grow rapidly; and it is expected that it will include about 50 billion connected heterogeneous devices and almost anything in the environment. This growth will result in an enormous increase in demanding reliable wireless connections. It is obvious that IoT will present a brand new life style by embedding IoT into various applications like in industry, environment, smarts building and smart cities, smart grid, smart energy management, health care, education, internet of vehicles, smart security, smart farming, smart transportations, smart homes [5,6]. But one of the main challenges that arise from the massive number of IoT devices is the spectrum scarcity which results in the merge of cognitive radio concept with the IoT.

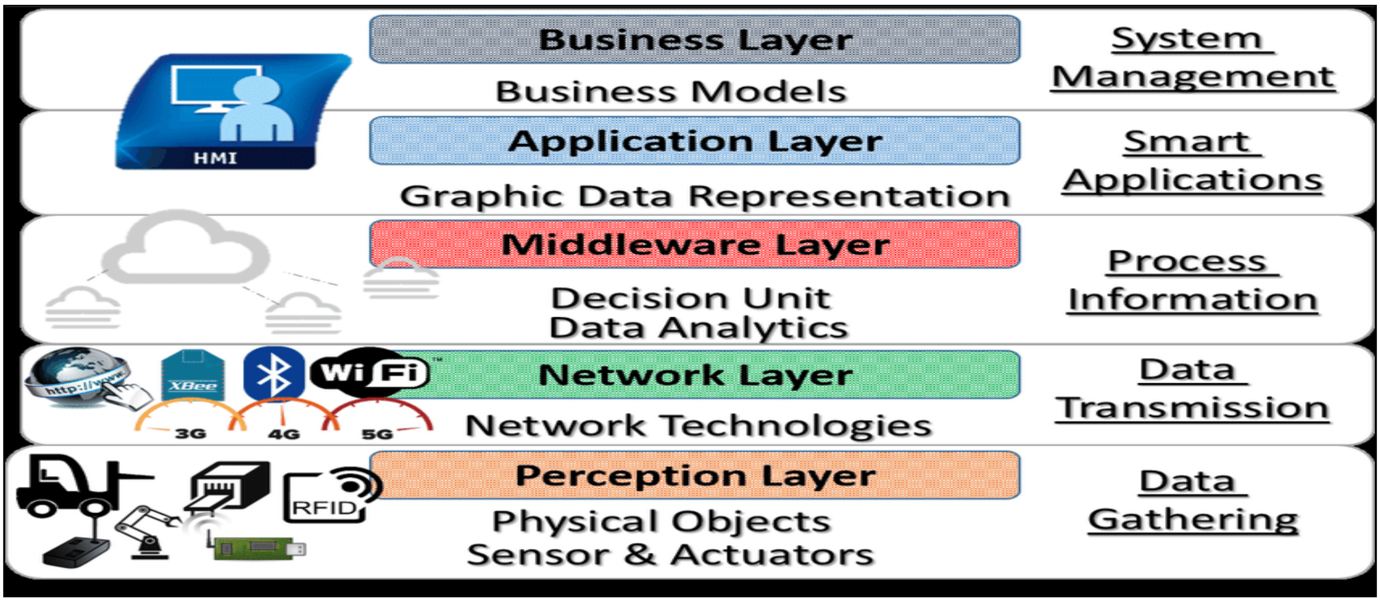

Fig- 1. Five Layered Architecture of IoT

4. COGNITIVE RADIO NETWORKS

There is an existence of significant amount of spectrum band potentially available for the long run deployment in CR networks which does not seem to be used at all by the operators. A communication technique was introduced in 2000, and it was named as "Dynamic Spectrum Access Networks" or "Next Generation (xG) communication network" or "Cognitive Radio Networks (CRNs". It allows the unlicensed users (or Secondary Users or SUs) to share and access the licensed spectrum band with its original users (or Primary Users or PUs). This is done with minimal interference with them and without any degradation in their Quality of Service (QoS) [11].

Cognitive Radio (CR) is an intelligent flexible communication device that interacts with its surrounding environment to be aware of its radio frequency environment, location, internal state and application needs. The radio can use this information to adjust and regulate its operating parameters (e.g. transmitting power, modulation scheme, communication technology, operating frequency) instantaneously in order to reconfigure itself to achieve the desired communication objectives.

In CRN, the subsequent four functions are required [12,13] that are stated below:
1. Spectrum Sensing: to detect the unused bands of licensed spectrum, called as 'spectrum holes'.
2. Spectrum Management: estimating the Quality of Service (QoS) of the spectrum holes and selecting the appropriate spectrum band that meets the communication requirements.
3. Spectrum Mobility: It is the ability to deliver the service with no interruption when accessibility has been successful and a transaction has been initiated, and adapt to fast changing in the environments.
4. Spectrum Sharing: maintaining fair spectrum scheduling technique among SUs.

The four main functions of the cognitive radio networks are represented into a cycle called the cognitive radio cycle [3] as shown in figure 2.

The CRNs is split into two main categorizes, a primary network and a secondary network [3,14]. The PU ownsthe licensed band and consists of primary base station (BS). The secondary network(s) usually consists of the cognitive radio base station (CR-BS) and the CR users. In case of centralized medium access control (MAC) protocol, the secondary network includes an intermediate system that is responsible for sharing and distributing the resources ofthe unused spectrum among different CRNs. But in case of distributed MAC, different CR users are responsible for deciding when to access the unused frequency channel.

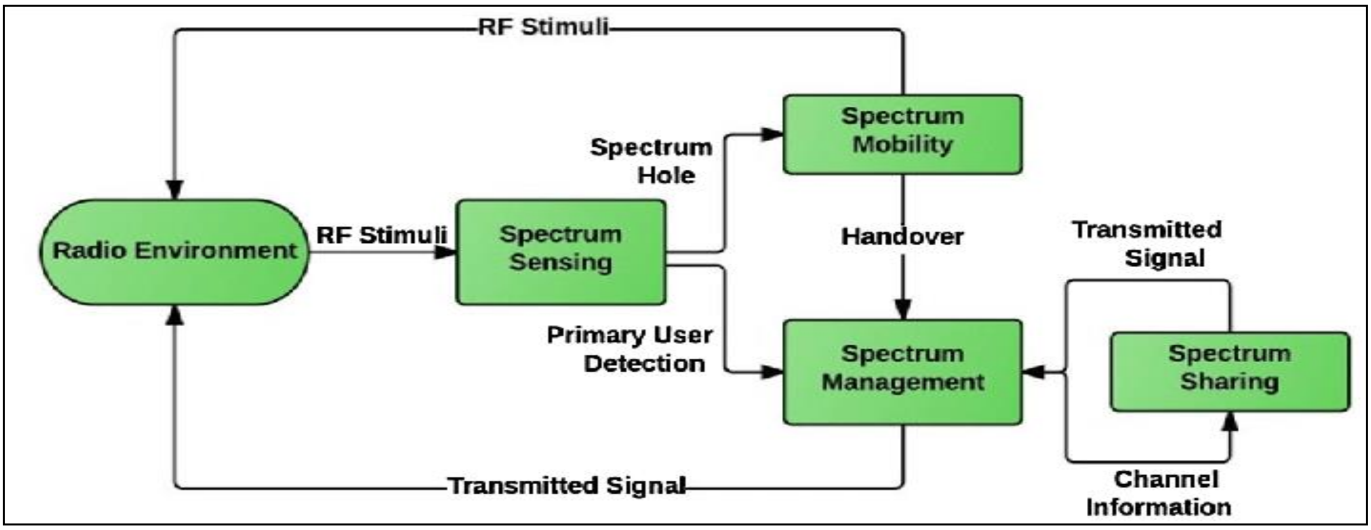

Fig- 2. Cognitive Radio Cycle

CRN is employed in numerous applications like military networks,cognitive mesh networks, leased networks, disaster relief and emergency networks, public safety networks, cellular networks, medical applications, TV white spaces, weather forecast, trafficcontrol, mining and Internet of Things, etc [12]. The different challenges of CRN include accurate sensing, signaling, self-coexistence, optimized spectrum decision, cross layer design, seamless spectrum handoff, and energy efficiency [6].

5. COGNITIVE RADIO INTERNET OF THINGS

The continuous huge growth in IoT concept and application has lead to massive amount of information need to be sent on the spectrum band. But the operators suffer from spectrum scarcity. Spectrum scarcity not only depends on channel availability but also depends on the spectrumutilization and the technologies used for implementing CRN. The standard fixed spectrum assignment policy to the current spectrum has become inadequate. A solutionis to purchase the spectrum which will be uneconomical. There is a continuous variation in the parameters of the environment, the spectrum allocation and utilization, and the cost of purchasing the spectrum. Due to this, it is envisioned that IoT won't be able to grow as estimated without the integration ofthe CR abilities and the IoT technology. In other words, the IoT willsuffer from spectrum scarcity as the number of IoT objects will increase, and there will not be enough spectrum allocated for it. Thus, IoT networks need to have cognitive radio capabilities. IoT objects must be able to use the licensed unutilized spectrum band, whichshall increase the spectrum efficiency by providing opportunistic access of the spectrum bands to the IoT objects.

An efficient and economical solution to the IoT spectrum scarcity problem is the usage of CRN to ascertain the IoT smart network. CR technology can be merged with the IoT to be called as "Cognitive Radio Internet of Things (CRIoT)". CRIoT can be utilized in many applications such as smart health care, smart transportation, etc. The merged technologiesshould satisfy many network parameters such as channel availability, allocation delay, reliability, high throughput, energy efficiency, end-to-end delay, etc. Many communication standards and technologies have to be used to cope up with the increase of connectivity among different IoT applications and services that use the CR technology. For example, Bluetooth, ZigBee and Wi-Fi are used for the indoor smart environment and cellular system, IEEE 802.11af, weightless etc. are used for the outdoor environment Both short and long range communication shall be supported with the capabilities of CRN [6].

The IoT smart networks shall perform various functions. Itwill capture the interference free channels in the presence of PU. It estimates the QoS of the detected holes and provides continuous communication if any IoT object changes its operating channel. It then regulates the licensed spectrum access for the huge number of IoT objects with minimal interfering with the PUs [6].

The design factors for CRIoT system include [15]:
1. The application in which the CRIoT system is employed and consequently its characteristics;
2. The technology used for communication between devices and its characteristics;
3. The regulation imposed the country using the system that include licenses, allowable interference and certificates.

Cognitive Radio Internet of Things (CRIoT) is merging the cognitive radio capabilities with the IoT technology such that the IoT can use the licensed spectrum to solve the issues of spectrum scarcity and to use the spectrum effectively [6].

6. COGNITIVE RADIO INTERNET OF THINGS CHALLENGES

The various challenges for CRIoT depend on the existing network structure and the designed application scenario [16,17]. These challenges are given below:

1. **Standardization**: One of the major challenges in the development of IoT applications include the existence of multiple technologies. IEEE 802.22 is a standard for wireless regional area network that uses the white spaces in (TV) frequency spectrum. This standard can be considered as a step for CRN standardization.

2. **Mobility**: CRIoT system must work perfectly with the change of topology and change of spectrum holes in the band.

3. **Availability of resources**: Most IoT applications have a large number of IoT objects over the identical network; which in turn, require considerable network resources to be enough to support theiroperations.

4. **Energy consumption**: CRIoT will consume considerable electrical energy especially in the spectrum sensing phase. But theenergy consumption has to be as low as possible. Efficient prediction of the spectrum holes can be considered as a good solution. Also energy harvesting must be taken into consideration to be able to provide sufficient electrical energy to access the channel.

5. **Scalability**: IoT applications will connect million or perhaps billions of IoT objects over the identical smart network. Extendable services and operations must be developed to tolerate new services and devices joining the network constantly.

6. **Coexistence of Heterogeneous Communication Devices or Inter-operability**: There is an existence of heterogeneous devices and protocols that need to operate with each other in IoT environment where the systemneeds to work with several heterogeneous devices, technologies, standards,and protocols.

7. **Reliability**: Reliability among different IoT objects is must to access the licensed spectrum dynamically as it can be required to change some transmission parameters such as transmission power, modulation mode, channel selection, antenna parameters, etc. Therefore, the spectrum allocation function would require multiple variable optimization process, which will increase the complexity of the allocation process. The IoT objects may have different QoS requirements such as delay constraint, energy consuming rate, packets dropping rate constrains, etc. The required spectrum allocation must be fast in order to meet several objectives in an IoT network.

8. **Distributed networks types management**: IoT network is predicted to be composed of a large number of IoT objects existing in various forms of networks with various topologies and specifications. These networks will have different configurations, communications techniques, failures and performance. They must negotiate with each other and be self-organized to effectively share the network resources.

9. **Security**: Hackers can change anything to control and manage the IoT devices, such as channel information, energy consumption, or any other resources. High security shall be required to ensure integrity of the transmitted data. Which in turn, can lead to high complexity in the network.

10. **Proper Hardware Design**: Proper hardware design of CRNs results in effective utilization of the entire network. Another critical issue is the antennas associated with CRNs. Antennasused in one frequency spectrum (say, in cellular network) are not identical in size as compared to the those used in some other spectrum (say, in ISM 2.4GHz band). Moreover, the degree of transmission power varies in nature with respect to the location. Some gateways are required to provide connectivity of different IoT objects to the networks. Flexibility, security, scalability, and energy efficiency of the gateways are truly important in the design procedures of IoT networks In multi-user scenario, efficientspectrum utilization should be maintained properly. Usually, CR users seek for its access to the spectrum independently. Properly designed gateways may perform faithful spectrum sensing for them. Geo-location based spectrum searching with previoussearch statistics could be a good solution. Two other concerns, flexibility and interoperability should be up to the mark to meet the requirements [18].The IoT is a combination of heterogeneous objects. The CR technology that includes node-based architecture with proper controlstrategies is an efficient solution for heterogeneous networks. However, this yields to some security issuesas uniform security standards is not applicable to all heterogeneous networks. This is often a main concern for CR based heterogeneous network.

Regularization and standardization has been a vital point of conflict that needs to be addressed on priority basis. The legal aspects for the usage of the CRNs in licensed spectrum needs to be addressed by concerned agencies as no unlicensed wireless application wouldbe allowed to access to the ownership spectrum without proper permissions. This could create inconvenience, threat to security & surveillance and also disrupt the services to the PUs. The proper detection of presence of PUs is most crucial i.e. categorization between the PU's signal and the SUs signal could be a challenging task. In addition, presence of multiple licensed users will have variety of signals in the same band which is another key challenge [19].

7. A SURVEY ON SPECTRUM ASSIGNMENT SCHEMES IN COGNITIVE RADIO INTERNET OF THINGS

In Table 1, spectrum assignment protocols for CRIoT is classified into two types, spectrum sharing and spectrum allocation. This section surveys all the problems of CRIoT spectrum assignment.

Table 1. Channel Assignment Classification for CRIoT

Protocol used by various authors	Proposed Idea by the authors	Sharing/ Allocation	Centralized/ Distributed
B.Zhang et al.(2013) [20]	PUs leases their surplus portion to IoTs.	Sharing	Distributed
B. Moon (2017) [21]	Both PUs and IoTs work together to improve their performance, by deriving the blocking probability for the PUs and carried traffic for the IoTs.	Sharing	Centralized
H.Kim. et al. (2017) [22]	Based on the conditional interference distribution, using stochastic geometry, derive the optical transmission capabilities for all the IoTs.	Sharing	Distributed
J.Wen. et. al (2018) [23]	Find the optimal positions of the secondary information gathering stations used to collect the information for the IoTs and then find their optimal operating channels.	Sharing	Distributed
L. Qu et al. (2012) [24]	A new spectrum allocation system model using Homo Egualis Social Model.	Allocation	Centralized
R.F. Shigueta et al. (2014) [25]	Based on the traffic history, the IoTs allocate the channels, using probability theory.	Allocation	Distributed
S.Kim (2017) [26]	Using inspection game to distribute the free sensed slots between various IoTs.	Allocation	Centralized
X.Liu et al. (2017) [27]	Derive an equation to unify the hoping moment for all IoTs, in order to minimize the rendezvous time between various IoTs.	Allocation	Distributed
S. Mohapatra et al. (2018) [28]	Use of Round Robin Tournament to guarantee rendezvous between the communication pair between two IoTs, in an asymmetric asynchronous manner.	Allocation	Distributed
J. Zhu et al. (2018) [29]	Use Markov decision process- based model to describe the state transformation of the system, and Deep learning to solve the problem of packets transmission from different buffers.	Allocation	Distributed
R. Han (2018) [30]	Consider multi-hop concurrent data flows, where successive links form a routing path. Use non-dominated Sorting Genetic Algorithm-II to maximize a multi-objective function.	Allocation	Centralized
H.B. Salameh et al. (2019) [31]	Using linear programming to find the optimal distribution of idle blocks (guard bands) among CRIoT transmissions.	Allocation	Distributed

7.1 Spectrum sharing

In spectrum sharing there is cooperation between both the PUs and the SUs (or IoTs). In other words, the primary network(s) leases its vacant slots to the IoTs, without degradation of the QoS of the PUs. This section surveys some ofthese protocols.

In [20], authors have proposed a cooperative transmission model between the SUs and the PUs. The model is incorporated by leasing the frequency spectrum from the primary network to the SUs. It is done to improve and enhance the utilities for both the PUs and SUs. Game theory is introduced in the paper to solve the resource sharing problem. Nash Bargaining Solution (NBS) and selective cooperation are used for acquiring the intended optimal leasing strategy. The modeling used is a cooperative two-player bargaining game between the PUs and the SUs. Initially, a PU broadcasts a Request-to-Send

(RTS) to inform its Primary Receiver (PR) by its minimum transmission rate. The PR thenanticipates the channel's condition and calculates the transmission rate. The PR replies by a Clear-to-Send (CTS), if the channel meets the required transmission rate. All SUs receive both RTS and CTS messages. The PU will cooperate with a SU if the transmission rate of the PU is less than the minimum transmission rate. Each of the SUs will calculate the bargaining game parameters. The sum of utilities for both the PU and the SU can be maximized, if the best optimization is selected depending on the calculation of best strategy. The PU utility is the sum of the gains fromboth the changing transmission rate and power saving. The SU utility is the sum of the energy consumption and achieved transmission rate. Each SU sets a timer, and the first one whose timer runs out will send a Partner-to-Send (PTS) that includes the best cooperative strategy between this pair. Finally, when the PU and the other SUs receive the PTS message, that SU will be chosen to share the channel with that PU. Simulation results has shown that leasing the spectrum whilst using cooperative game theory will enhance the sum of utilities for both the PUs and the SUs. The main disadvantages of this method is that the processes performed are too complicated to be done by an IoT device due to its limitedcapability. Secondly, the performance of the proposed protocol isnot compared with any other protocol in this paper. Thirdly, less number of IoTs were used to evaluate the protocol.

In [21], authors have proposed a dynamic spectrum access (DSA) technique for IoTs which uses cognitive radio-enabled low power wide area networks (LPWANs). This network runs in both the unlicensed and licensed band. The main objective is to maximize the spectrum capacity of unlicensed users, while never interfering with the licensed LPWAN primary users. An assumption is made that the entire spectrum band is divided into various sub bands. Each PU can use an A-band channel including several sub bands. Each SU can use a B-band channel which consists of only one sub band. The A-band and B-band channels overlap with each other. The PUs can operate on the overlapped band. The existence of SUs is completely unknown to the PUs. Therefore, if a PU aimed to usea channel in the overlapped band while the channel is occupiedby a SU, the SU has to instantly vacate the channel and occupies other available unlicensedchannels. If there is no other vacant channel, the SU fails to varyits operating channel, and they are queued at the top of the SU's queue. When the number of PUs running calls reached its maximum or there are no enough vacant channels and if a PU call is needed, it willbe blocked and cleared. The SU's requests queued are served as a first come first served (FCFS). The authors in [21] have derived an equation to calculate a cutoff value to determine the ratio of the overlapped area that is divided between the PUs and the SUs. This value hasto be selected carefully so an adequate tradeoff between exaggerated delay experienced by the SU calls and the availability of further spectrum. Simulations and the numerical analysis are used to evaluate the proposed strategy in the paper. The results proved that the proposed technique maximized the spectrum capacity for the SUs while maintaining the QoS for the PUs. The main disadvantages of this strategy are as follows: First, blocking of PU calls is an option. Second, as the channel holding time for PU calls increases, the average dwell time for SUs calls also increases. Third, in case of high PU load, the queue size may grow infinitely. All of these disadvantages lead to the conclusion that the proposed protocol cannot deal with real time packets. Finally, the performance of the proposed protocol is not compared with any other protocol.

In [22], a distributed cognitive random access algorithm has been proposed. The authors have assumed that CRIoT network has wired spectrum sensors used for communication with various mobile IoTs as it is impractical for mobile IoT to sense the spectrum. The authors have proposed that based on the measured interference by the sensor, the IoTs shall adjust their probability of transmission. Using the level of interference obtained from the sensor, stochastic geometry was used to derive a conditional interference distribution at each IoT. The optimal transmission probabilities for all the IoTs were calculated using the calculated conditional interference distribution. A simple algorithm to assign each IoT its corresponding probability was derived. To evaluate the proposed algorithm spectral efficiency was compared with conventional ALOHA schema. Simulation results in the proposed algorithm in the proposed work has lead to better spectral efficiency. Its main disadvantage is that it uses ALOHA protocol which is a very old protocol to compare the results. Also, its architecture needs extra hardware devices.

In order to collect the information for all IoTs migrating in the area, the authors in [23] suggested the use of Secondary Information Gathering Stations (SIGSs). To find the optimal positions of the SIGSs and optimal operating channels for IoT devices, they have derived equations. To solve the problem, particle swarm optimization was used. They used a fitness function that attempted to maximize the number of SUs and their capacity and conserving the primary network transmission, considering the primary and secondary capacities and the appearance probability, the signal to interference-plus-noise ratio (SINR). As per simulation results in the proposed work, the proposed algorithm works well in achieving the objectives. It is found that while comparing to the Random Resource Allocationalgorithm, the number of supportable IoTs for the proposed algorithm is increased by about 20%. Its main disadvantages are, firstly, they supposed that the PUs are controlled by a primary operator, so there is no possible interference from them. Secondly, many assumptions are taken, such as SUs already have information about the PU's Base Stations, its location and the operating channel. Finally, its architecture needs extra hardware devices which will be uneconomical.

7.2 Spectrum Allocation

In spectrum allocation, the IoTs network(s) is responsible for finding the vacant slots by themselves (through sensing). It also decides how to use the sensed vacant slots.

Authors in [24] developed a spectrum allocation model based on Homo Egualis (HE) social model. It is a non-cooperative gamemodel. The HE agents are the players that predicts future behavioral strategy (accessing probability) in the next cycle, based on the collected information from various nodes. Among all the nodes, the distribution of the spectrum is done periodically. Accessing probability is used to establish the nodes' next cycle behavioral strategies in order to use the available detected spectrum holes effectively and fairly. The desire to pursue imparity is inversely proportional with the good of playing for players in the HE game. The node's access probability is calculated based on the information like priority and communication time, number of occupied and available channels,. This probability will be used to initiate the node's next cycle behavioral strategy with the HE community access schemes periodically, in order to use the available detected spectrum holes. Simulation results proved that this model improved the spectrum utilization. The main disadvantages of this model are, first its architecture needs added hardware devices. Secondly, less number of IoTs are used to evaluate the performance. Third, the performance of the proposed protocol is not compared with any other protocols. Lastly, having single node channel leads to using the channel effectively but unfairly.

In [25], the authors presented a distributed spectrum allocation technique for IoT objects when merging the CR technology. This technique uses the traffic history for next channel allocation. The technique used is divided into three main parts: (i) the periodic distribution of Hello messages to inform the SUs of the vacant channels, (ii) the next part is the initial allocation algorithm, which is executed whenever a node is added to the network, or when the topology or a channel changes. First, the links leading to the added node is prioritizedin a list based on their previous traffic history, and then each of these links is given a channel based on its order in the list. Based on the calculated priority of the node, it determines whether it will be responsible for channel assignment or it will receive the assignment from another node. (iii) The last part is the interaction messages, which aresent by any node that changes its allocated channels, in order to inform the other nodes about that change. Upon receiving these messages, the nodes update their priority and run an algorithmto re-compute the channel assignment, taking into account the appearance of a PU at any moment. Simulation results proved that this technique shows better performance in terms of aggregated throughput and packet delivery rate, but moderate performance for both reduced interference and end-to-end delay compared to the two other techniques used in the paper to evaluate the performance. The main disadvantages of this method are, first the processes performed by each IoT are too complicated, and an IoT may even be responsible to assign channels to others. This is disliked due tothe IoT's limited capability. Second, the number of IoTs used to evaluate the protocol is small.

Game theory was used in [26], where a cooperative algorithmfor both spectrum sensing and sharing in CRIoT was proposed.Authors used an inspection game, with one inspector the cognitiveradio base station, and multiple inspectees that inspects the IoTs. The aim of thealgorithm was to maximize the network throughout while maintaining fairness among various IoTs. Having minimum and maximum sensing rate for the BS and the IoTs, and the minimum and maximum spectrum slots needed for each IoTs, the authorsderived equations to calculate the following parameters at each period of time. (i) The utility of each IoT and for the base station, (ii) the relative utilitarian bargaining solution for each IoT and for the cognitive basestation, (iii) the aspiration level for each IoT, the sensing rate update foreach IoT, and (iv) finally the aspiration equilibrium. The above calculated parameters are used to propose an algorithm for thespectrum sensing and sharing of IoTs. The spectrum sensing rate and allocation for each IoT are randomly initialized. Then the above parameters are calculated iteratively to change the values of spectrum sensing rate and allocation for each IoT until the aspiration equilibrium value is satisfied. To evaluate the proposed algorithm, a simulation model was built to compare its performance with that ofthe Adaptive Cooperative Spectrum Sensing (ACSS) and Decentralized Cooperative Spectrum Sensing (DCSS) algorithms. Simulationresults proved that the proposed algorithm overcome both algorithms in terms of spectrum efficiency, fairness and throughputloss ratio. The proposed algorithm works whenever a vacant slotis sensed, but the derived equations are too complicated to beapplied in real time, especially in the case with huge number of IoTs. Also the number of IoTs used to evaluate the protocol is too small.

In [27], the authors addressed the problem of device to device (D2D) communication for IoT devices considering priority, wherethe two devices need to meet each other on a common availablechannel. To achieve this, they proposed a priority channel hoppingtechnique. The technique divides the time into a number of time slots where each timeslotserves a number of IoTs and other devices. At the start of a time slot, the IoTdevice senses the network to obtain the available channel set, i.e.the channels not used by any other device at that time. The timeto rendezvous is the time spent by an IoT source to meet with itsdestination in a time slot. This time is to be minimized for a priority packet. In case of a non-priority packet, only the source do thesearch, while the destination only listens. The source puts thepacket on a free channel, while the destination only scans thechannels until it finds its packet on the right one. But in case of apriority packet, both the source and destination work together tofind the free channel. As the rate ofchannels and IoTs are different, the time to sense the channelsare not equal, so an IoT can sense only one channel in a slot, whileanother IoT can sense more than one. This leads to a problem ofnot recognizing the exact time of rendezvous. The authors thenderived an equation to unify the hopping moment for all IoTs. This mapping between the sensed channels for both the source and destination leads to the right channel they should communicate on.Comparison between this technique and an enhanced jump stay protocol was done. Mathematical and simulation in the proposed work proved that both techniques achieved 100% successful rendezvous rate, but the proposed protocol acquired less delay for high priority packets compared to another one. The main disadvantages of this method are, first the processes performed by each IoT is too complicated so they need extra capabilities. Second, the number of used IoTs to evaluate the protocol is small. Third, the energy consumption increases when the number of channels is more than fifteen.

In [28], the authors have addressed the problem of rendezvous between two SUs in CRIoT network, but in an asymmetric asynchronous manner. The concept of Round Robin Tournament (all- play-all tournament) is used to guarantee rendezvous between the communication pair. It uses a fair tournament, as each SU plays every other SU. It gives all the SUs the same opportunities and prevents one bad game from eliminating a SU from the competition. Simulation results proved that the proposed protocol performs better than the old existing channel hopping algorithms in terms of the average time to rendezvous, the degree of rendezvous, andthe throughput. The main disadvantages of this method include the process performed by each IoT is extremely complicated, and thus it needs special capabilities for the IoTs. Second, the number ofused IoTs to evaluate the protocol is small.

The authors in [29] proposed a scheduling mechanism based on deep learning. The authors assumes that packets are stored in multiple buffers, and there exist multiple channels to be used. The authors aims to reach an adequate strategy to send packets from the buffers overthe channels. A Markov decision process model was used, where a state represents the channel or buffer state, and an action represents the selected channel used to transmit the packets waiting their turn for the selected buffer. Authors supposed that channels and buffers take several states corresponding to the communication pair and transmission mode. In each time period and for regular states, packets are selected from a particular buffer to be sent over a particular channel. If the channel state is poor, packets are not transmitted. If a new packet arrives and the buffer is full, a chosen packet (may be the oldest) is lost. Deep learning (Q-learning) is used to map the transition between different states. It gets the optimal actions by continuous interaction with its surrounding area, using trial and error in a constant way. Simulation is done for evaluation for comparing the proposed scheduling with the strategy iteration algorithm. The simulated results proved that it had lower performance than strategy iteration algorithm, but the complexity is extremely reduced. It also can work without any prior information. The main disadvantages of this method are, first the complicated processes to be performed at each IoT, which is disliked due to IoT's limited capabilities. Second, it has lower performance than thestrategy iteration algorithm. Third, the number of IoTs in the simulation is too small. Finally, the buffer size should be carefully chosen to decrease the number of lost packets.

The Non-dominated Sorting Genetic Algorithm-II was used in [30], in order to solve the multi objective problem of maximizing both the spectrum utilization and the network throughput in a CRIoT networks. Considering multi-hop concurrent data flows, where a routing path is composed of successive links. Graphtheory was used to model the network considering nodes, links, spectrum channels and multi-hop concurrent data flows. Using this model, equations were derived in order to maximize boththe throughput and the spectrum utilization considering signal- to-interference-plus-noise ratio. A solution of the problem is formed by successive spectrum channels (links) presenting the routing path. Different solutions (chromosomes) were chosen to form the initial population, and then the Non-dominated Sorting Genetic Algorithm-II was applied to reach the optimal solution. The proposed algorithm was compared with adapted Strength Pareto Evolutionary algorithm, and the simulation resultsproved that the proposed algorithm performs better than the other one. It reached better solution, with lower speed to reach this optimal solution using large and diverse population. The main disadvantages of this protocol are: first the number of IoTs in the simulation is small. Second, genetic algorithms usually take a long time, which let the algorithm cannot work in real time, especiallywith high number of IoTs, i.e. it is not scalable. Also the throughputrate does not increase as it should with the increase of the number of flows.

The objective of any spectrum allocation is to serve as many as number of IoTs as possible. A Guard Band (GB) is needed to avoid adjacent channel interference, when dealing with large numberof low-cost IoT devices equipped with CR capabilities. Supposing the spectrum is divided into three types of blocks; idle blocks, data blocks and busy blocks (those used as guard bands). The technique proposed in [31] solved the problem of finding the optimal distribution of idle blocks among IoTs. The proposed work attempted to maximize the throughput by reducing the number of assigned data-plus-GB channels, taking into account each device's demand rate, interference and total transmit power constrains. The authors proposedan algorithm to solve this problem using channel bonding and data aggregation. The algorithm consists of two phases, block assignment phase and release of extra channels post processing phase. For the block assignment phase, sequential fixing linear programming procedure is used. For the second phase, first the block with maximum size is selected. Then the maximum number of channels starting from the left sided guard band of the block is released, taking into consideration the satisfaction of the rates conditions. Finally, the guard band is added again. To evaluate the proposed protocol, it is compared with two older protocols. Simulation results proved that the proposed protocol achieved higher spectrum efficiency and also higher throughput than the two other older protocols. The main disadvantages of this protocol are, first as it is an NP-hard problem,so the solution is suboptimal. Second, the number of used IoTs to evaluate the protocol is too small.

The disadvantage of the distributed spectrum allocation is that the process is too complex to be performed by the IoTs. Also in all protocols, the number of IoTs used for evaluation is small, sometimes even too small (about 10) which is not logic, as usually the number of IoTs to be served in an area is in the orderof thousands.

6. CONCLUSION

IoT presents a new paradigm by developingvarious applications. However, in order to avoid the spectrum scarcity, IoT needs integration of the Cognitive Radio Networks (CRNs) capabilities. Integration of CRNs and IoT seems to shift the future of sophisticated wireless networks to new heights. But still both CRN and IoT are at developing stage and are a great areas for research. Although researchers are focusing on the use of cognitive radios in IoT but they have not presented motivations behind the paradigm thoroughly in detail. In future, there would be billions to trillions of IoT objects that would be in need of seamlessspectrum access. Traditional communication technologies cannot combat with these circumstances. So, there is a dire need of a transformation fromordinary IoT objects to cognitively capable objectswhich enables IoT objects to handle with spectrum congestion situations. It can envisage that IoT without cognition functionalities will be nothing buta burden on existing network infrastructure. Having been leveraged by acquiring cognitive capabilities, IoT objects can efficiently exploit spectrum resources available radio spectrum is a constraint and underutilized. It is expected studies and researches will be strong and meaningful enough to overcome the issues and challenges associated with integration of IoT and CR.

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