Distributed Cooperative Ai Techniques for Cognitive Radio Networks

Ganesh Babu Rajendran, Amudha Veerappan

Abstract**:** ***Cognitive radio has emerged as one of the Next Generation(xG) wireless communication systems and dynamic spectrum access utilization in next generation cellular networks. In this paper, a literature survey of many spectrum sensing techniques are studied and the comparative results are analyzed. Also the challenges and techniques that are involved in spectrum sensing is discussed in detail. Cooperative Sensing based Artificial Intelligence(AI) technique provides preferable stability and scalability because of its low complexity under dynamic Primary Users(PUs) activity. Cooperation between Secondary users to avoid interference, reduce the average time to sense the primary users and to solve the hidden node problem.***

Index Terms**:** ***Internet of Things; Architecture.***

I. INTRODUCTION

A wireless mesh network is offered with a high speed Internet connection. However, with the increased network density, the network needs more capability to meet the applications[1]. Cognitive Radio (CR) technology supports more software flexibility and affordability features than other radio classes. CR is a radio with intelligence for spectrum sensing, spectrum sharing, and spectrum management with self-aware capability[2]. The NeXt Generation(xG) cognitive radio architecture can be classified as primary network and secondary network. The incapable existing spectrum usage can enhance the opportunity to access the authorized license bands without interfering the main users[3]. The primary network component is Primary Users(PUs) and primary base station. Similarly the secondary network component is CR users and CR base station.

Transition of better spectrum of the xG network is maintained by the seamless communication requirements[4].The main network can support cooperative leased communication network with a third party to access licensed radio spectrum without any interferences[5].The process of dynamically accessing the unused spectral bands(spectrum holes/white spaces) is known as Dynamic Spectrum Access (DSA)[6]. The xG network can access the existing spectrum by keeping priority communication and response time without requiring the infrastructure[7].In conventional radio, there is no ability to change the parameters dynamically and spectrum band in response to the environment interferences. Spectral efficiency in the CR networks, cooperative features incorporated with spectrum sensing and spectrum sharing to each other[8]. In this paper we study and evaluate the various narrowband, wideband, cooperative and interference based optimized sensing techniques. This paper is structured as follows: Section 2 presents the different schemes of cooperative spectrum sensing techniques. Section 3 concludes open research issues and challenges in this paper.

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II.REVIEW OF LITERATURE

In the survey, literature review for narrowband, wideband, cooperative and interference based sensing techniques has been presented. Different schemes of spectrum sensing techniques can be classified in Figure 1.

A. Cooperative Sensing Techniques

In cooperative spectrum sensing selective CR users cooperate to detect unused spectrum bands with non cognitive users. It has centralized coordinated, distributed coordinated and uncoordinated schemes..

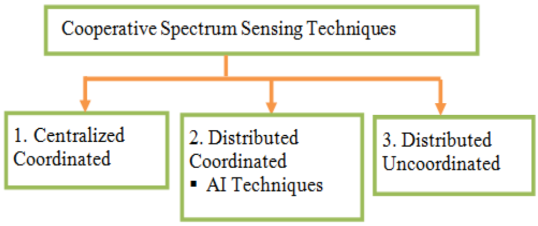

Figure.1. Different Schemes of Cooperative Spectrum Sensing Techniques

B.Survey on Centralized Coordinated Sensing Techniques

Jasim and Al-Anbagi (2017) proposed spectrum scarcity, dynamic accessing the cog- nitive radio networks are comprehensively investigated in this study. The Dynamic Spectrum Access (DSA) technology access the better spectrum communication of the NeXt Generation (xG) network and is maintained without spectrum space, by allowing CR to operate any one of the best available spectrum band. The performance of spectrum utilization is affected by the received interference power constraint. The limited natural resource is available from electromagnetic radio spectrum and as the number of wireless devices dramatically increase, the problem of the spectrum scarcity will be more complicated.

Nhan Nguyen-Thanh and Insoo Koo (2013) developed selective CR users cooperate to detect unused

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spectrum bands with non cognitive users. Cooperative spectrum sensing schemes optimize the cooperation overhead, reporting sensing time, energy consumption and minimizing bandwidth requirements. Optimum number of users to cooperate in a hard combinations like OR, AND, and M out of K rules. The fusion rules such as OR, AND, K out of N is the decision rule. Each cluster in the cluster head is not fixed but randomly selected for each time interval over dynamic spectrum access and optimally makes the final decision. Fusion Centre (FC) collects all local sensing information to make the final decision where non cognitive users present or absent in the spectrum band.

Shinde and Jadhav (2016) proposed data Fusion Centre (FC) is used to collect the common available channel information from CR user independently. Then the FC determines the presense of PUs sensing information and then decides cooperative CR user to coordinate sensing information. In this approach, CR users collects the information about the channel usage and update its spectrum information. After a particular time interval it transmits the information to the centralized controller. The centralized unit facility initiated to multiple CR users performing at different time measurements. Thus the performance will increase heavy data transmission burden and provide final decision about the presence of licensed user with a more time delay.

Tulika Mehta et al., (2013) discussed on cooperative sensing case, where all cognitive users tries to check the availability of unused primary channel. After the detection, that is reported back to Fusion Centre (FC). The main problem of report phase affects the PUs interference when CR users transmit results to FC. To avoid this problem, relay based selective cooperative approach exist in all CR users on the detection of performance.

C.Survey on Distributed Coordinated Sensing Techniques

Zhiqiang Li et al., (2010) designed that each cooperative users will dependently detect the channel and share the information in a distributed manner by improving the channel efficiency with either decrease the bandwidth or increase the data rate. The CR user doesn't have any centralized controller unit. Each CR user collects local sensing information and distribute to other users. Multiple CR users are cooperative to check the availability of unused primary channel. Thus the performance will reduce heavy data transmission burden and provide final decision about the presence of licensed user but with less time delay. Synchronization between each node is cooperative to detect the vacant channel essentially. Cooperative spectrum sensing is used to reduce the false alarm probability by both licensed and unlicensed users.

Akyildiz et al., (2006) designed unlicensed band architecture by the xG network. Here there is no authorized users, all xG users have equal rights to use the spectrum bands. Multiple CR user appears in the same portion area and communicate using same spectrum band efficiently to improve the spectrum usage and suited high QoS by sharing intelligent spectrum algorithm. xG networks can operate the personnel military applications to perform secure spectrum handoff. xG user is cooperated to detect the available spectrum and improving spectrum utilization among the users.

Helen Tang et al., (2012) designed cognitive users and are able to shift the frequency of operation from one mode to another mode. When non cognitive users present in the particular spectral band, cognitive users would vacate newly available vacant spectrum band immediately. The Random Walk Mobility Model (RWMM) is used to provide movement pattern creation among the particular users and reduction of energy detection. Most of the mobility model includes information about velocity, location, speed and direction that can range from 0 to 360 degrees, acceleration change over time. Thus the cooperative performance is achieved high throughput with a low control overhead. The sensitivity of Cooperation within nodes extremely decrease approximately to -25 dBm.

Haijun Zhang et al., (2016) proposed all Femtocell Users (FUs) to increase the network capacity under resource allocation and mitigate co-tier/cross-tier interference constraints. Based on the QoS requirements, allocate the channel selection to users either maximum or minimum number. Both spectrum sensing and resource allocation improve the minimum user data rate requirements. Cognitive femtocell networks cooperate between primary macrocell users and secondary femtocell users. The Femtocell architecture has the ability to access spectrum through cognitive Femtocell Base Stations (FBS) and improve cellular coverage and mitigate the interference.

Owayed et al., (2010) proposed cooperative decision of logical 'AND' and 'OR' rule with multiple CR users. Distributed Cooperative spectrum sensing is used to reduce the noise, fading and shadowing effects. The detection performance of a spectrum sensing techniques can be evaluated using the Probability of False Alarm (PFA) and Probability of Detection (PD). The Receiver Operating Characteristics (ROC) curves of logical OR is better than the logical AND rule. The sensing technique achieved the high detection probability and a low false alarm probability among CR users.

Hillenbrand (2005) proposed the probability that a CR correctly decides that the spectrum is busy, when primary transmission is taking place. Thus, sensing performance can be improved by probability of detection higher is better. A specific value of average SNR, gives low probability of false alarm results in a high probability of detection. It performance is best in lower SNR value.

Arora et al., (2015) discussed the probability that a CR user falsely decides that a PU is present in the available spectrum band when the spectrum is actually free. The performance of detector under various values of probability of false alarm is low for SNR values. Thus the simulation performance is to achieve a low false alarm probability.

Shanmugavel et al., (2017) proposed energy detection to detect the unknown PU (Primary User) signal based on energy of the received signal. If the noise power is known, the unknown signal is optimally detecting the performance. CR users check the availability of PUs. Since the performance of received SNR signal is susceptible to noise power uncertainty. If the noise power is uncertain, the energy detector will not be able to detect the signal reliably as the SNR is less than a certain threshold, called an SNR wall. In addition, the energy detector can only determine the presence of the signal but cannot differentiate signal types thereby, the energy detector often results in false detection triggered by the unintended CR signals.

Suliman et al., (2015) proposed the probability of false alarm rate increases, prob- ability of missed detection rate is very low and achieved low spectrum utilization. On the other hand, interference to the primary users by the probability of false alarm is low and missed detection probability is high. In order to achieve a constant false alarm level by set the threshold. During the detection of the threshold level is adjusted from lower to higher and maintain a constant false alarm probability. This methodology is called as constant false alarm rate (CFAR) detection.

D.Survey on Distributed Coordinated AI Techniques

Xu Dong et al., (2010) discussed each neuron is responsible to produce a single output value by accumulating inputs from different neurons through a activation function. The number of input nodes depends upon parameters we considered for training and the output depends upon the classes we want to classify. The hidden nodes are random which are still in research .Each link connection is specified with particular weight. The weights are updated during training by Back propagation algorithm. Neural networks provide signal detection, modulation identification and classification in cognitive radio networks. The classifications of signal processing perform simple multi operations on the data module. A cognitive radio is a reconfiguration network where it accepts any type of modulation in the signal received and reconfigures itself accordingly. There are different types of network topology used in ANN called feed forward and feed backward.

Ramiyar Heydari et al., (2014) presents the concept of Hidden Markov Models(HMM) arises from the well-known Markov chain and emit physically observable symbols. Only the input and output states are observable directly where the intermediate states are hidden (observed in Bayesian sense) that is why the name is HMM. HMM is significantly having more applications in speech processing and in machine vision compared to observable Markov models. In cognitive radio networks, information is processed and the channel condition statistics are studied to yield whether channel is occupied by primary or secondary user. It is capable to improve classification of modules and measure the particular distance between different states.

Le and Ly (2008) discussed that Fuzzy Logic(FL) is based on mathematical theory of fuzzy sets, which is a classical set theory. Instead of binary classification, fuzzy logic introduces degree of closeness to output which is a more human behavior classification than binary. The fuzzy classification is based on reasoning flexibility which accounts uncertainties and inaccuracies. For context aware reasoning Fuzzy logic is the best choice. Fuzzy logic is used for spectrum sensing techniques, where compromise decision making is required. Fuzzy operators NOT, AND and OR enables to combine different conditions to make a decision. FL takes input from different types of information to make a model which is simple and human understandable way.

Morabit et al., (2015) presents Evolutionary Algorithms(EA) and are more random in nature, that's why they are very close to understand the spectrum situations to classify primary or secondary in an efficient way compared to HMM. Genetic Algorithm(GA) approach begins by defining structure of a chromosome with important genes. Genes are considered for CR frequency, modulation, power and BER. Each gene is contributing for the decision making process. Assumption has been made that fitness function is equally dependent on all the four parameters. The fitness function uses weighted sum approach in GA. All the four parameters set as an equal weight to each other. The input is given by Secondary User (SU) or application for QoS requirement are compared against the population of chromosomes. GA has the capability of multi objective optimization, so that overall fitness is computed as the cumulative sum of the individual fitness of each parameter (gene).

Zhao and Lai (2012) discussed decision based on past learning used for Case Based Reasoning (CBR) method. It is one of the artificial intelligence methods proposed. In case based reasoning, giving solution to a problem is generated by choosing the past cases which is most relevant to the current problem. Just like optimization adapting to a particular case consumes less time when compared to solving each and every problem that arises. Sometimes case based reasoning may fail if searching of a relevant problem takes long time. In such cases combination of artificial intelligence methods may be imparted. Since Cognitive radio works in the principle of context reasoning, i.e., the environment awareness applications mostly depends upon the past situations of climatical conditions sensed. If the condition is new it will be stored as a database for the future cases.

Huazi Zhang et al., (2012) proposed energy efficient clustering for cognitive radio networks. If any of SUs node position altered or PUs are dynamic to the CR network, then the whole network associated with re-clustering processes becomes less stable and involves more control overhead. At the time of re-clustering, the rest of nodes positions and clustering structure remains the same. When anyone of the PUs change, only 2 of 50 SUs nodes can't control the node position and it also gets affected. In this case, the network once again converge stability by the two merges.

Syed Ali Fathima and Sumitha et.al., (2014) utilizes the best energy efficient protocol on LEACH to diminish the energy consumption and it can develop the lifetime of Wireless Sensor Networks(WSN). Clustering procedures can be used to talk with cluster head and base station. In the event that sink station is distant from the CH, energy consumption will be raised and it can diminish the lifetime of WSN. To overcome these, Particle Swarm Optimization(PSO) strategies is actualized with this protocol in serial to achieve most astounding lifetime of WSN. PSO is used to augment the adaptable and energy efficiency. It is definitely not hard to complete and the change estimation rate to a great degree rapidly. PSO technique to improves lifetime performance of the network. Using optimization technique we first create clusters and cluster head selection based on energy. After this whole process data transfer begins for this node on shortest path.

Vipul Vyas and Anurag Monda (2016) presented that heuristic PSO is efficient, effective and, essay optimization algorithm. It is used to investigate the discover position. It is essentially actualized and it can be associated for both investigative research and designing use. In PSO, a global fitness capacity is utilized by every one of the particles in the swarm. It possess the greater optimization capacity and finish effortlessly. The energy consumption and unwavering quality are checked with topology control which is the issue in LEACH protocol. The double PSO technique is to determine the Disjoint Set Cover (DSC) issues in the WSN. The DSC issues is to isolate the sensor nodes into different disjoint gatherings and timetable them to work one through one in serial to keep energy while at the equivalent time meets the surveillance need, e.g., the complete scope target of DSC is to maximal the quantity of disjoint. PSO rely on upon algorithm that is used to put the optimal sink spot to the nodes to make the network with more efficient energy.

Xingjuan Cai et al., (2008) proposed on dispersed PSO oversee calculation try to decrease radio force while ensuring availability of the network. It reduces the amount of hidden nodes and asymmetric associations on the amount of hidden nodes and upside down joins at the season of rising the exchange force of a subset of the nodes may, actually, rise the benefit of the sensor network. Creator produces topologies with less hidden nodes and asymmetric associations than a practically comparable calculation.

Kiran Kumar Anumandla et al., (2013) proposed Firefly Algorithm(FA) with the optimization tool to perform current space along self-improving process from previous stages. Brightness has direct proportionality with attractiveness and considers two fireflies; one of them with less brightness which will be attracted to the greater brightness. If no brighter firefly is found than the given one, the motion will be random. The objective function has associated with brighter. The light intensity is inversely proportional to the squared distance and directly proportional to the source intensity brightness. After that Fireflies are ranked and obtain the current best cost function. The Base Station(BS) is recognized set of optimal CHs and corresponding to cluster members. The BS transmits CH-ID information to each nodes in the network.

Senthilnath et al., (2011) discussed that the clustering using firefly technique can be categorized into two types: hierarchical and partitioned clustering. Hierarchical approach is the large number of hierarchy cluster into small number of cluster with nearby centroid. It has two methods: (i) the agglomerative method, two or more smaller clus- ters merged into a large cluster; (ii) the divisive method, divides a longer cluster into two or more smaller clusters. The partitional clustering tries to divide a set of disjoint clusters from the data set without forming hierarchical structure. The prototype based partitional clustering is creating cluster centers and advance classify into the data set.

Manshahia (2015) presents compared to PSO, the main differences are the lack of search velocities and the use of an inverse-square law to guide interactions between all search processes. It can't be parallized all the portions of firefly can determine the next movement of a firefly. FA can deal with multi-modal optimization problems naturally and sensitive to scaling of design variables. It is a highly non linear attraction mechanism.

Pal et al., (2012) discussed PSO in the search space that whole population is not automatically subdivided into sub-swarms. For each iteration, each search process up date its velocity so that its path turns slightly towards the best solutions seen by a subset of the search processes. It doesn't require the light intensity using the objective function. PSO is slow convergence in refined search space and weak local search ability. It has the less flexibility of integration with other optimization techniques. It is simply linear mechanism.

Sarma and Gopi (2014) discussed on Jumper Firefly Algorithm(JFA) at the base station instead of Firefly algorithm. Every population of creatures live with quality and fitness among the members with diversity function. In general low quality members are not able to reach high quality achievements. Each population quality is estimated with respective members and qualifies the probability situation to obtaining the eligibility. In order to avoid that problem the author developed JFA to improve appropriate solutions by making the changes to eligible situation and find the optimal solution by status table. From the status table it is observed that all the current situation records help to change the new suitable situation by the jumping process. This process executes on search agents(fireflies) to jump the option to make the decision process. In the status table each and every firefly location is situated particular search space at ith stage and fitness maintain solution quality at ith stage by the fireflies. Every firefly worst solutions attain by searching phases. After the search process the cost of each firefly qualification is investigated from the status table.

E. Survey on Distributed Uncoordinated Sensing Techniques

Akyildiz et al., (2011) proposed each cooperative users will independently detect the channel and uncoordinated to share the information by distributed manner. In distributive approach, there is no centralized unit instead shared detecting information among multi nodes. The CR user doesn't have any centralized controller unit. If any of PUs appear in the spectrum environment, CR user should vacate the vacant location to occupy the channel and doesn't inform to other users. Moreover, all these sensing information is essential to be linked with receive node through multi hops. Thus, the performance will increase heavy data transmission burden and provide final decision about the presence of licensed user with less time delay.

Xuefei Zhang et al., (2015) stated that multi CR users experience with invalid channel detection by uncoordinated distributive scheme. Uncoordinated sensor node activity is not directed for proper mobility to reach sensing observation. Each CR user doesn't require perfect synchronization to detect the channel selection and increased time delay interference. Both forwarding probability function and back off function are independent of node location. By improving uncoordinated resource allocation the forwarding probability determines number of nodes (or equivalently transmissions) involved in the cooperative forwarding process and transmission success probability performing the packet eventually arrives at its destination within a designated amount of time. Every node makes forwarding decision independently without prior coordination with its neighbors and even without being aware of their existence. The greedy forwarding algorithm, which is labeled as GF: it chooses the node, which has received a copy of the packet and would like to forward, closest to the destination in each hop as the forwarding node. Greedy forwarding algorithm is comparatively easy to implement. However it relies on coordination between nodes to determine the set of nodes which have received packet and would like to forward and to determine which node among them is closest to the destination. Proposed uncoordinated scheme has a similar performance as the coordinated Greedy Forwarding (GF) and Sparse Permanent (SP) algorithm but saving a large amount of coordination overhead.

AyshaEbrahim et al., (2016) proposed distributive uncoordinated resource allocation to eliminate the signaling overhead caused by message broadcasting. However, distributed resource allocation introduces a new challenge that arises independent resource allocation that can maximize the throughput of individual cells but does not lead to better network wide performance. Since femtocells do not receive Channel State Information (CSI) reports from their neighboring users, and hence are unable to detect their presence, femtocells need to extract additional information from the environment to estimate the quantity of User Equipment's (UEs) located within their coverage range by monitoring the Up Link (UL) interference originated by those UEs. Uncoordinated resource allocation proposed a low-complexity algorithm named F-ALOHA, which is considered an enhanced version of ALOHA. F-ALOHA allocates the shared spectrum between femtocells in a distributed manner by randomizing the interference avoidance. However, this technique leads to inefficient allocation of resources due to the randomly generated patterns and lack of planning. The uncoordinated algorithm is presented with a conflict graph and is created based on random graph theory to model the probability of interference between femtocells in order to achieve the optimum resource allocation. Game theoretic approaches were presented where non cooperative to achieve the optimal resource allocation. The distributed interference mitigation scheme is based on the machine learning strategies. The proposed method requires an iterative process to analyze the spectrum and quantify the detected interfered users. Therefore, the complexity becomes higher as the number of iterations increase. The algorithm assumes that no information exchange between femtocells is possible and that each femtocell learns by taking a set of actions and forms its own allocation strategies to reduce interference accordingly.

III.CONCLUSION

The literature survey on the various Spectrum sensing methods, their advantages and drawbacks are explained by different authors. From the above proposed Distributed Coordinated AI techniques of PSO, FA, JFA is used to avoid the interference further between licensed and unlicensed users, reduce the sensing average converge time and save minimum node power consumption. Finally, we present several open research issues for implementing spectrum sensing.

REFERENCES

1. Kaushik MK, Yoganandam Y, Sahoo SK.Sensing and Sharing Schemes for Spectral Efficiency of Cognitive Radios. International Journal of Electrical and Computer Engineering. 2018; 8(5): 2934–2941.
2. Yu Y, Ji Y, Wang W, Zhang Y.Adaptive Two-Stage Sensing in Cognitive and Dynamic Spectrum Access Networks. TELKOMNIKA Indonesian Journal of Electrical Engineering.2014; 12(5): 3257–3265.
3. Mahajan R, Bagai D.Improved Learning Scheme for Cognitive Radio using Artificial Neural Networks. International Journal of Electrical and Computer Engineering. 2016; 6(1): 257–267.
4. ArslanH. Cognitive Radio. Software Defined Radio, and Adaptive Wireless Systems. Netherlands.Springer. 2007.
5. Mitola J. Software Radio Architecture: Object-Oriented Approaches to Wireless System Engineering. John Wiley & Sons Ltd. 2000.
6. Biglieri E, GoldsmithAJ, GreensteinLJ, MandayamNB,PoorHV.Principles of Cognitive Radio.Cambridge University Press. 2013.
7. Chen K-C, PrasadR. Cognitive Radio Networks. John Wiley & Sons Ltd. Chichester. UK. 2009.
8. KhattabA, PerkinsD, MagdyB. Cognitive Radio Networks-From Theory to Practice. Springer Series.Analog Circuits and Signal Processing. 2009.
9. JasimAM, Al-AnbagiHN.A comprehensive study of spectrum sensing techniques in cognitive radio networks. Proceedings of IEEE Int. Conference Current Research in Computer Science and Information Technology (ICCIT). Slemani. Iraq.2017; 107–114.
10. Nguyen-Thanh N, KooI.A Cluster Based Selective Cooperative Spectrum Sensing Scheme In Cognitive Radio.EURASIPJournal on Wireless Communications and Networking.2013; 1(176): 1–9.
11. ShindeSC,JadhavAN.Centralized cooperative spectrum sensing with energy detecion in cognitive radio and optimization.Proceedings ofIEEE Int. Conference Recent Trends in Electronics Information and Communication Technology (RTEICT). Bangalore. India.2016;
12. MehtaT, KumarN,SainiSS.Comparison of Spectrum Sensing Techniques in Cognitive Radio Networks.International Journal of Electronics and Communication Technology.2013; 4(3): 33–37.
13. LiZ, YuFR, HuangMA Distributed Consensus-Based Cooperative Spectrum-Sensing Scheme in Cognitive Radios.IEEE Transactions on Vehicular Technology.2010; 59(1): 383–393.
14. AkyildizIF, LeeW-Y, VuranMC,MohantyS.NeXt generation/dynamic spectrum access/cognitive radio wireless networks: A survey.Computer Networks Elsevier.2006; 50(13): 2127–2159.
15. TangH, YuFR, HuangM, LiZ.Distributed consensus based security mechanisms in cognitive radio mobile ad hoc networks.IET communications.2012; 6(8): 974–983.
16. ZhangH, JiangC, MaoX, ChenH-H.Interference Limited Resource Optimization in Cognitive FemtocellsWith Fairness and Imperfect Spectrum Sensing. IEEE Transactions on Vehicular Technology 2016; 65(3):1761–1771.
17. Owayed AA, MohammedZA,MosaAAR.Probabilities of Detection and False Alarm in Multitaper Based Spectrum Sensing for Cognitive Radio Systems in AWGN.Proceedings IEEE Int. Conference Communication Systems (ICCS). Singapore. 2010; 579–584.
18. HillenbrandJ.Calculation of Detection and False Alarm Probabilities in Spectrum Pooling Systems. IEEE Communications Letters2005; 9(4): 349–351.
19. AroraK, SngalTL, MehtaT.Simulation of Probability of False Alarm and Probability of Detection Using Energy Detection in Cognitive Radio.International Journal of Computer Science and Technology.2015; 6(1): 37–41.
20. ShanmugavelS, BhagyaveniMA,KalidossR. Cognitive Radio: An Enabler for Internet of Things. Netherlands .River Publishers.2010.
21. SulimanIM,LehtomakiJ,UmebayashiK.On the effect of false alarm rate on the performance of cognitive radio networks.EURASIP Journal on Wireless Communications and Networking.2015;1(244): 1–17.
22. DongX, LiY, WuC,CaiY.A learner based on neural network for cognitive radio.Proceeding IEEE Int. ConferenceCommunication Technology (ICCT). Nanjing. China. 2010; 893–896.
23. R. S. Heydari, Alirezaee, Makki SV, AhmadiM,ErfaniS.Cognitive radio channel behavior prediction using the hidden Markov model.Seventh Int. Symposium Telecommunications (IST). Tehran.Iran.2014; 993–998.
24. Le H-ST, LyHD, Opportunistic spectrum access using Fuzzy Logic for cognitive radio networks.Proceeding IEEE Int. ConferenceCommunications and Electronics (ICCE). Hoi an Vietnam. 2008; 240–245.
25. MorabitYE, MrabtiF,AbarkanEH. Spectrum allocation using genetic algorithm in cognitive radio networks.Third International Workshop on RFID and Adaptive Wireless Sensor Networks (RAWSN).Agadir Morocco.2015; 90–93.
26. ZhaoZ-J, LaiH-C.A cognitive engine based on case-based reasoning quantum genetic algorithm.Proceeding IEEE Int. ConferenceCommunication Technology (ICCT). Chengdu. China. 2012; 224–228.
27. ZhangH, ZhangZ,ChauY.Energy efficient spectrum aware clustering for cognitive radio sensor networks. Chinese Science Bulletin2012; 57(28–29):3731–3739.
28. Syed Ali FathimaK. SumithaT.To Enhance the Lifetime of WSN

Network using PSO.International Journal of Innovative Research in Computer and Communication Engineering 2014; 2(1): 1–6.
29. VyasV,MondaA.PSO Based Clustering Approach for WSN. International Journal of Emerging Technologies in Engineering Research2016; 4(10):48–52.
30. CaiX, CuibZ, ZengJ, TanaY.Dispersed particle swarm optimization.Information Processing Letters.2008; 105(6): 231–235.
31. AnumandlaKK, KudikalaS, VenkataBA,SabatSL.Spectrum Allocation in Cognitive Radio Networks Using Firefly Algorithm.Proceeding Int. ConferenceSwarm, Evolutionary, andMemetic Computing (SEMCCO2013).Chennai. India. 2013;366–376.
32. SenthilnathJ, OmkarSN, ManiV.Clustering using firefly algorithm: Performance study, Swarm and Evolutionary Computation.Elsevier. 2011; 1(3):164–171.
33. ManshahiaMS.A Firefly Based Energy Efficient Routing in Wireless Sensor Networks. African Journal of Computing and ICT 2015; 8(4): 27–32.
34. PalSK, RaiCS,SinghAP.Comparative Study of Firefly Algorithm and Particle Swarm Optimization for Noisy Non Linear. International Journal of Intelligent Systems and Applications 2012; 4(10): 50–57.
35. SarmaNVSN,GopiM.Energy Efficient Clustering using Jumper Firefly Algorithm in Wireless Sensor Networks. International Journal of Engineering Trends and Technology2014;10(11): 525–532.
36. Akyildiz IF, LoBF,BalakrishnanR.Cooperative spectrum sensing in cognitive radio networks: A survey. Physical Communication 2011; 4(1): 40–62.
37. ZhangX, TaoX,CuiQ.Uncoordinated Cooperative Multihop Forwarding in 2D Highly Dynamic Networks. International Journal of Distributed Sensor Networks 2015; 11(8): 1–13.
38. Ebrahim A, Alsus E,Baidas MW.An Uncoordinated Frequency Allocation Scheme for Future Femtocell Networks.Proceedings IEEE Int. Conference Wireless Communications and Mobile Computing Conference (IWCMC). Paphos. Cyprus. 2016; 239–243.
39. Ganesh Babu, R. “Helium's Orbit Internet of Things (IoT) Space.” International Journal of Computer Science amd Wireless Security 3.2 (2016): 123-124.
40. Ganesh Babu, R. “Mismatch Correction of Analog To Digital Converter In Digital Communication Receiver.” International Journal of Advanced Research Trends In Engineering and Technology 3.19 (2016): 264-268.
41. Ganesh Babu, R. and Dr.V.Amudha. “Analysis of Distributed Coordinated Spectrum Sensing in Cognitive Radio Networks.” International Journal of Applied Engineering Research 10.6(2015): 5547-5552.
42. Ganesh Babu, R. “Resource Allocatıon in QoS Schedulıng for IEEE 802.16 Systems.” International Journal of Science and Innovative Engineering & Technology 1.5 (2016): 50–55.
43. Rajesh, M., and J. M. Gnanasekar. "Path Observation Based Physical Routing Protocol for Wireless Ad Hoc Networks." Wireless Personal Communications 97.1 (2017): 1267-1289.
44. Rajesh, M., and J. M. Gnanasekar. "Sector Routing Protocol (SRP) in Ad-hoc Networks." Control Network and Complex Systems 5.7 (2015): 1-4.
45. Rajesh, M. "A Review on Excellence Analysis of Relationship Spur Advance in Wireless Ad Hoc Networks." International Journal of Pure and Applied Mathematics 118.9 (2018): 407-412.
46. Rajesh, M., et al. "SENSITIVE DATA SECURITY IN CLOUD COMPUTING AID OF DIFFERENT ENCRYPTION TECHNIQUES." Journal of Advanced Research in Dynamical and Control Systems 18.
47. Rajesh, M. "A signature based information security system for vitality proficient information accumulation in wireless sensor systems." International Journal of Pure and Applied Mathematics 118.9 (2018): 367-387.
48. Rajesh, M., K. Balasubramaniaswamy, and S. Aravindh. "MEBCK from Web using NLP Techniques." Computer Engineering and Intelligent Systems 6.8: 24-26.