OPTIMAL SOLUTIONS FOR RESOURCE ALLOCATION IN A CRAHN FOR ECO FRIENDLY ENVIRONMENT

Ashima Rout[1], Ramesh K Sahoo[2], Sunita Dhalbisoi[3]

[1,3]Department of ETC Engineering, IGIT, Sarang,Odisha, India,

[2]Department ofCSE &A, IGIT, Sarang,Odisha, India,

Corresponding author: Ashima Rout, ashimarout@igitsarang.ac.in, ashimarout@gmail.com

ABSTRACT:

Channel assignment in CRAHN (Cognitive Radio Ad Hoc Network) is defined as a critical issue during any kind of communication to be executable. It is a problem of determining an optimal mapping between the accessible licensed channels and the cognitive radio channels such that the performance of CRAHN is optimized. The objectives of the channel assignment in this concerned network are to assign the available channels to cognitive radio interfaces of cognitive nodes to achieve proficient spectrum utilization, to diminish the interference among cognitive or secondary nodes, and to curtail the interference to PUs (primary users). Thus, motivates the necessity for optimization during spectrum sensing in a cognitive radio system. This paper has narrowly focused on optimized spectrum allocation problems by developing new algorithms under a platform of Non-dominated Sorting-based Genetic algorithm (NSGA-II), Heuristic Harmony Search (HS), Cuckoo Search (CS), and Multi Objective Bat Algorithm (MOBA) by weighted sum method. The assessment of optimal solutions in terms of true pareto-fronts has been discussed towards ensuring eco-friendly environment in context with channel allocation.

Keywords- CRAHN, PU, Cognitive Radio, Spectrum Allocation

1.INTRODUCTION

To meet the recent challenges in the rapidly expanded service demands, it is mandatory to materialize the needs by means of integrating and merging fundamental wireless access network infrastructure like ad-hoc, cellular, and broadcasting schemes as well as optimizing the communication resource coordination towards various applications. In this context, to synchronize wireless network resources by integrating services for different applications under various spectrum regulations, it is inevitable to possess a cooperative, flexible, and reliable communication node. Hence, to provide ever-present and un-interrupted connectivity with integrated access and dynamic services, it is advisable to have a platform that is favorable for multi-band, multi-mode re-configurability being having operational environment around it. A hopeful explanation to such a problem in above scenario is CRAHN with its intellect ability required to realize the optimal performance that is to be projected under dynamic and random situations [1].

It is very much understood that CR (cognitive radio) is supported behind a concept of SUs (secondary users) might have sufficient transmission opportunity to assure their service quality due to the underutilized behaviour of channel by the primary system. Under such circumstances if SUs fails to find the means of increasing their transmission opportunity, then the quality of service (QoS) of the secondary network will be meticulously ruined. Thus, necessary action is to be taken up to increase the network throughput by creating additional transmission opportunity of CUs (cognitive users) without affecting primary service quality [2]. Analysis of various optimal techniques in the field wireless domain has become inevitable towards achieving solutions for various challenges experienced in CRAHN domain.

2. OPTIMIZED SPECTRUM ALLOCATION

The spectrum scarcity problem experienced by FCC (Federal Communications Commission) in a wireless domain can be improved [3][4] by making implementation of CR concept that holds the ability of sensing, analysing, decision making, and mobility which also has the aptitude of altering its transmission parameters like energy, frequency, modulation, coding strategies etc. by learning its environmental status, then adapting itself in dynamic circumstances to make certain an optimal usage of presently accessible resources and simultaneously accomplishing desired Quality of Service (QoS) [5]. Performance enhancement along with avoidance of interference to other licensed users is an alternaive objective of CRAHN.The transmission parameters persuades different characteristic features ofcognitive radio's performance. Hence, optimization of CR is a dynamic multi-objective optimization problem [6].The literature behind the purpose of cognitive radio being preserving its spectrum utilization efficiency, we may concurrently proceed for attaining other objectives to focus upon spectrum allocation very precisely. Resource optimization being too crucial and essential we may give attention to accomplish maximization of throughput, and spectral efficiency along with transmission power and interference minimization. This confronts one of the resource allocation problems which may be resolved by several optimal solutions. Other allied parameters during transmission in CRAHN as per the specified purpose of an individual user may be considered while generating the multi-objective functions towards an optimal solution. These may be classified as Bandwidth (B*)*, Symbol Rate (R_s), Bit rate (R_b), Coding rate (R_c), modulation Index (*m*), Frame length (L), Time Division Duplex (*TDD*) i.e., transmission time in percentage, Transmission Power (*P)* etc. The environmental parameters may include path loss, noise power, signal-to-noise ratio (SNR) in decibel (dB), information regarding spectrum, etc. [7]. Lot many works have been carried out specifying sensing approach of a spectrum in a CR environment. A problem for finding out better individuals is supposed to be decided towards the decision of next generation in [8], proved in a kind of Non-dominated NeighbourDistribution (NNDA) algorithm for multi-objective function. Equivalent works have also been performed in multi-objective immune genetic algorithm (MIGA) with nondominated sorting principle in [9]. The basis of above two works is compared and evaluated with NSGA-II in [10] where no issue has been raised as to the realization of QoS which is of utmost importance. Transmission parameter adjustments in cognitive radio environment by using multi-objective EA that is based on non-dominated sorting genetic algorithm as an alternative to weighted sum type helped in discovery of a number of optimal solutions in [5]. Salient features of parameters related to environment may be thought of as input conditions of CRAHN systems whereas transmission parameters stated above may be treated as decision variables. In this context, at first, we have formulated our own objective functions with certain specific background conditions that are under a dynamic network topology, spectrum accessibility changing over space and time based upon a platform of NSGA-II as an optimization problem.We have proposed a new algorithm by building the objective functions with an aim to improve the functions in terms of parameters and thus it provides a better architecture of functions for superior and advanced optimization scenario.

3. OBJECTIVE FUNCTION DESIGN

The environmental parameters are to be taken out from the sensed information surrounded by the wireless environment. Next, by carrying out multi-objective optimization using various optimal techniques the probable solution is to be found out until the desired accuracy is congregated. Then the optimal solution has to be traced as pareto front for noting down the necessary values of transmission parameters as an output. A set of three objective functions are designed for maximization of throughput, maximization of spectral efficiency, and minimization of power consumption while the effects of probability of primary user interference duration has been analysed.

Throughput Maximization:

Upon focussing the definition as regards to the context of communication network may be Ethernet or packet radio network throughput or normally throughput is the rate of successful message delivered or accurate information received over a communication channel. The data these messages belong to may be delivered over a physical or logical link otherwise it can pass through a certain network node. Generally, this is measured in bits per second or bps. More precisely the system throughput may be defined as the sum of the data rates that are delivered to all terminals in a network. It is other way identical to digital bandwidth consumption. Hence, capacity optimization targets maximization of throughput which depends upon the transmission parameters mentioned above. The standardized objective function for throughput maximization for N_i subcarriers [5] may be expressed as described in equation (1).

$$f_{\text{thpt}}(\max) = \frac{m_i \times L_i \times R_{c_i} \times \text{TDD}}{N_i(O_i + L_i)m_{\max}} \text{------------(1)}$$

Where subscript 'i' denotes for i^{th}number subcarrier in the multicarrier transmission system and 'O' serves as an overhead concerning to the physical layer. 'L' being the length of the frame, 'N' being the noise power and 'm' represents the modulation index.$\text{TDD}$is the transmitting time in percentage.$R_c$is treated as the coding rate as defined earlier. However, focus being for a single carrier transmission system equation (1) can be simply modified as follows,

$$f_{\text{thpt}}(\max) = \frac{m \times L \times R_c \times \text{TDD}}{N(O+L) \times m_{\max}} \text{-------------(2)}$$

Similarly, other objective functions may be

Power Consumption Minimization:

The time varying features of signal in a wireless domain might cause more energy consumption upon experiencing packet losses, consequently retransmission becomes compulsory. The nodes possessing cognitive radio capability may be able to adjust their operating mode as per the channel variations. Thus, the transmission efficiency can be enhanced there by following a reduction in the power consumption [11]. In such a scenario, the objective function of power consumption minimizing [5] may be defined as,

$$f_{\text{pc}}(\min) = \left[\frac{(P_{\max} + B_{\max}) - (P_i - B_i)}{N_c \times (P_{\max} \pm B_{\max})} + \frac{\log_2(m_{\max}) - \log_2(m_i)}{N_c \times \log_2(m_{\max})} + \frac{R_{s\max} - R_{si}}{N_c \times R_{s\max}} + \frac{R_{c\max} - R_{ci}}{N_c \times R_{c\max}}\right] \times N_{\text{su}} \text{----(3)}$$

It It is therefore desirable to execute the communicating principle during mathematical computation with less power consumption. The parameters mentioned above during defining the objective function add values towards the fitness for minimization of power calculate for a number of secondary users $_{su}N$. Energy being the most important factor needs optimal usage for the communication process. Hence minimum power in terms of dB must be consumed for all the tasks during communicating or any type of computing [5].

Spectral Efficiency Maximization:

This is a measure of how efficiently a limited frequency spectrum is utilized by the physical layer protocol or at times by the media access control (MAC) protocol.In a more analogous way to network throughput this term makes us more accurate and transparent about its definition that this counts the total amount of information which may be transmitted over a given bandwidth in a specific communication system. The requisite parameters that would be essential in defining spectral efficiency are exactly the bit rate and the modulation index. Hence, the normalized objective function for spectral efficiency maximization [5] may be described as,

$$f_{\text{Speff}}(\max) = \frac{m \times R_b \times B_{\min}}{B \times m_{\max} \times R_{b\max}} \times 1/N \quad \text{--------------(4)}$$

Where $1/N$is the frequency reuse factor.

3.1 AN APPROACH TO PROBLEM DEFINITION

To find $\vec{g} = \langle P, B, R_s, R_b, R_c, m, L, TDD \rangle$ --(5) optimizes $\left[f_{thpt(\max)}\left(\vec{g}\right), f_{speff(\max)}\left(\vec{g}\right), f_{pc(\min)}\left(\vec{g}\right) \right]$(6)

Subject to: $l_i \le g_i \le u_i$, $i = 1,2,.................., D$

Where $\vec{g}$ is assumed as decision variable, n represents the number of objectives, D is the number of decision variable. l_i and u_i are the lower and upper bounds respectively. Here the decision variables are P, B, R_s, R_b, R_c, m, L, TDD

4. EXPERIMENTAL STUDY

4.1 NON-DOMINATED SORTING GENETIC ALGORITHM (NSGA)

Non-dominated sorting genetic algorithm (NSGA) [12] is a kind of mostly accepted non-domination based genetic algorithm for multi-objective optimization.Though it seems to be very effective algorithm, but failed to prove its excellence due tocomputational complexity and deficient in exclusiveness and selection of optimal parameter value. A modified version of the existing kind, NSGA-II [13] was developed which served a better sorting operation integrating superiority thereby there is no need of choosing parameters a priori.

4.2 HEURISTIC HARMONY SEARCH ALGORITHM (HS)

Heuristic Harmony Search (HS) algorithm [14] has been tried in a CRAHN setting that saves the bandwidth necessities among nodes serving as workstations. Due to the minimal computational complexities along with provision of competent channel assignment, the search process using HS algorithm as an optimization background have been worked out. The original objective function framed in the beginning performed as an optimization problem.

4.3 CUCKOO SEARCH ALGORITHM (CS)

Cuckoo search being an optimization algorithm put on a pedestal for its breeding behavior, and hence, can be applied for various optimization problems. It seems that it can perform well among other meta- heuristic algorithms in certain applications. The resemblance of cuckoo egg in a nest that represents a new solution here has been deliberately assumed as the transmission parameter(s) needed for optimization for several iterations to achieve better solutions in terms of maximization or minimization as the case may be. The number of existing host nests as the licensed spectrum is fixed. The fact of egg laid by a cuckoo is revealed by the host bird with certain probability. The similar concept has been experimented by considering the secondary users to discover a vacant and idle spectrum for its own transmission.

4.4 BAT ALGORITHM (BA)

Bat Algorithm has been considered as a platform to design an improvised and perfectness in explanations towards obtaining accuracy at par with diversity in this chapter. A new solution is formed using randomized efforts with the standard loudness of bats at that instant. The movements of bats in a flying condition are recorded arbitrarily with a pre-defined velocity at a position with a minimum assumed frequency, wavelength as well as loudness, so as to enable to detect its prey. The proposed optimization problem using BA has been experienced for a set of objective functions in a CRAHN environment.

5. SIMULATION STUDY ON OPTIMIZATION TECHNIQUES

Extensive study on various optimization techniques based on the designed objective function has been carried out in this paper. A statistic conducted on all above types of algorithms for a multi-objective optimization problem has been sited here with a justification and retrospective comparison as to which one serves a better result among all. In a nutshell, a model on cognitive radio parameter optimization has been formulated to address the spectrum allocation problem in a dynamic scenario. A bar graph has been shown here after simulation using Harmony Search, Cuckoo Search, Bat and Non-dominated Sorting based Genetic Algorithms using MATLAB tool. The transmission parameter optimization as mentioned above for throughput and spectral efficiency maximization along with power consumption minimization followed by a multi-objective function establishes the ground reality to choose the type of optimization scenario which will provide a set of solutions and optimal pareto fronts.

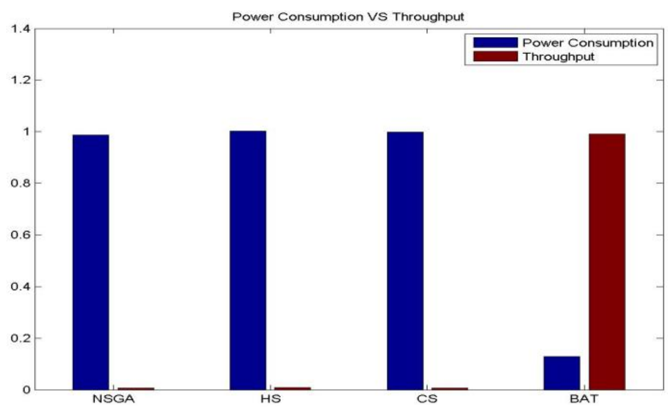

Fig 1: comparison bar graph between Power Consumption Vs Throughput

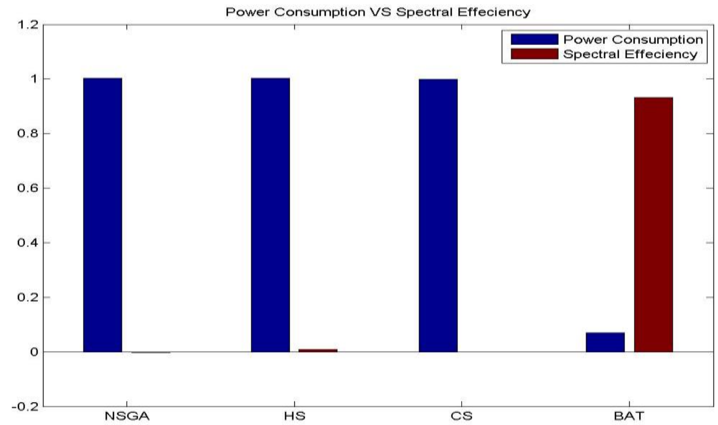

Fig 2: comparison bar graph between Power Consumption Vs Spectral Efficiency

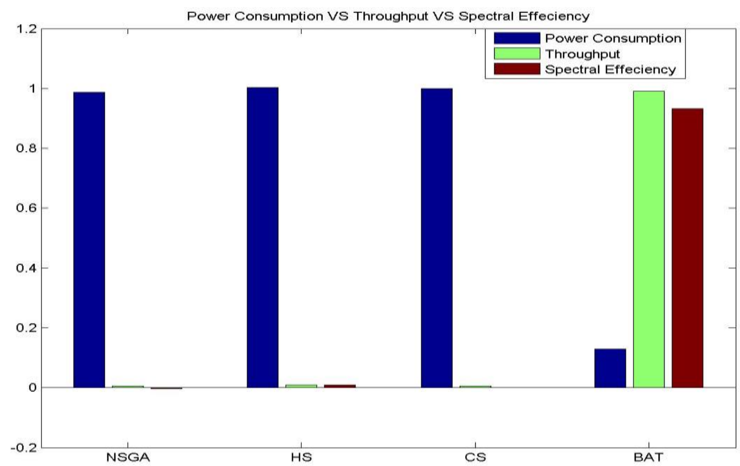

Fig 3: Power Consumption Vs Throughput Vs Spectral Efficiency of NSGA, HS, CS, BA

Upon moving through a case study on all kinds of optimization process mentioned above, the bar graphs are obtained as a result of simulation to visualise the best suited algorithm to define the designed optimization model. Fig 1 & Fig 2 explain a minimum of power consumption against maximum throughput and spectral efficiency respectively for the four kinds of algorithms adopted to solve the multi-objective optimization problem in a CRAHN environment to provide effective communication services to the cognitive users. Further, optimization status plotted for NSGA, HS, CS, and BA on a single stage for all the assumed parameters has been displayed in Fig 3. The analysis and findings of the above rank proclaim to choose Bat Algorithm for this work as an optimization process best fitted to provide the optimal solutions in terms of pareto fronts in a solution space since it presents the maximum throughput at par with spectral efficiency with a minimum energy or power consumption. The results of pareto front approximations have also been placed here for transparency in understanding the whole scenario. Thus, upon comprehensible observations bestowed on the bar graph and visualization of the limitations in NSGA-II, a suggestion to study the optimization process under platform of MOBA for achieving true pareto front solutions has been necessitated towards the paper justification.

6. RESULTS & DISCUSSION:

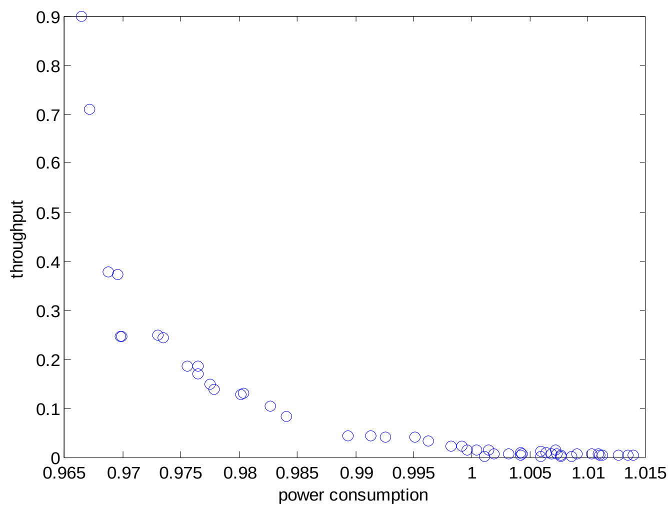

Fig 4: Pareto fronts for min_power consumption Vs max_throughput using MOBA (n = 50)

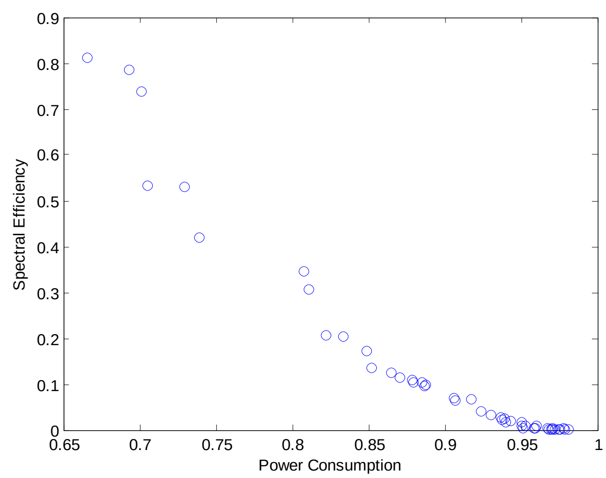

Fig 5 : Pareto fronts for min_power Vs max_spectral efficiency (n = 50)

Fig.4 has been traced for different values of population size, loudness, and pulse rate. A remarkable set of pareto fronts are obtained which show maximum throughput is decreasing with increase in level power consumption. In Fig. 5 the pareto fronts are plotted for power minimized fitness values and fitness for maximized spectral efficiency, which makes accuracy in achieving true pareto fronts for optimized power consumption, throughput & spectral efficiency.

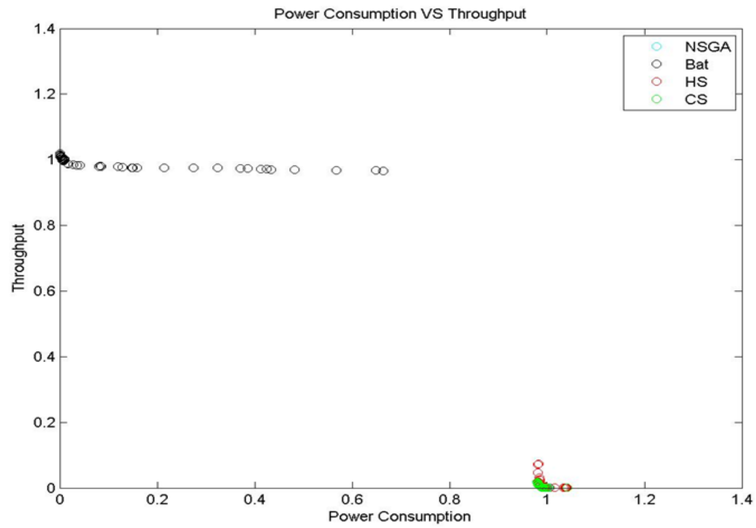

Fig 6: Pareto front solutions for NSGA, HS, CS and BA defining power vs. Throughput

In Fig.6, BA finds better spread of solutions than NSGA, HS, and CS optimization techniques as regards to power consumption and throughput on a single space. It is depicted from this plot that the throughput takes on a sharp rise even with a less amount of energy requirement upon realization under a platform of Bat algorithm. However, for other three discussed optimization problems, it is difficult to trace the throughput values even if the requirement of power takes on a sufficient value or alternatively speaking a higher amount of power is needed for a minimal and negligible amount of throughput.

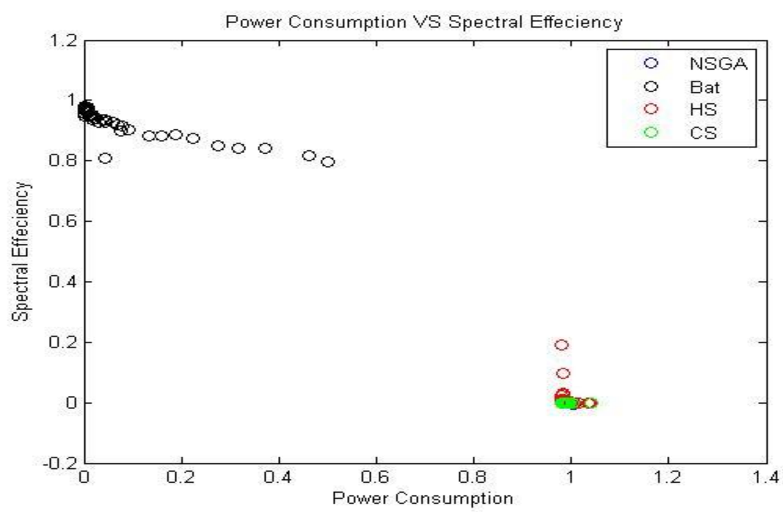

Fig 7: Pareto front solutions for power consumption Vs spectral efficiency for NSGA, HS, CS, BA

Similarly, in Fig.7 although it reveals a better estimation of spectral efficiency equivalently as throughput against proportionate power consumption, except BA, in all other types like HS, CS, NSGA do not provide a better value and rise in spectral efficiency. Thus, throughput and spectral efficiency maximization finds an improvised result only in case of BA thereby justifying the recent and proposed MOBA outperforms all three kinds of optimization techniques reflecting minimum energy consumption due to optimal usage of channel allocation in CRAHN which replicates the eco-friendly environment in the present state of digital world to exhibit communication.

7. CONCLUSION

The validation of optimal solutions during resource allocation in a CRAHN have been demonstrated through intensive study and designing new models in a multiple scenario. All the existing optimization methods which have justified their role for solving the associated complexities in CRAHN platform have been considered in this paper. Selection of reliable and suitable channel in terms of throughput and overhead have been found out after due sensing followed by detection process. Next, the optimal solutions in terms of obtaining true pareto fronts to describe throughput as well as spectral efficiency maximization and power consumption minimization have been achieved through simulation under MATLAB platform by following novel algorithms proposed in this paper work under varied optimization methods like HS, CS, NSGA and MOBA. The QoS during transmission by the secondary users dynamically and opportunistically in a licensed band is thus preserved avoiding the interference from primary users. The resulting solution set helped to analyze the performance of the solution space. Therefore, channel exploitation has been imperative for the unlicensed secondary users to grab available network resources and enhance resource utilization. The inference of all the results after analysis implies the minimal energy consumption due to optimal use of channel allocation in CRAHN which reflects the eco-friendly environment in the present scenario of digital world.

REFERENCES

1. Matin. M, Ahmed M, Ferdous N, “Spectrum Sensing and Throughput Analysis for Cognitive Radio an Overview”, Developments in Wireless Network Prototyping, Design, and Development: Future Generation, pp. 203-224, 2012.
2. Jae-Young Seol and Seong-Lyun Kim, “Optimal Opportunistic Rate Allocation in Cognitive Radio Ad Hoc Networks”, IEEE, Vehicular Technology Conference, pp. 1-5, Sep 2011.
3. Zhu, G.M., Akyildiz, I.F., Kuo, G.S., “STOD-RP: A Spectrum-Tree Based On-Demand Routing Protocol for Multi-Hop Cognitive Radio Networks”, IEEE Global Telecommunications Conference, IEEE GLOBECOM 1-5, 2008.
4. Etkin, R., Parekh A., Tse D, “Spectrum Sharing for Unlicensed Bands”, IEEE International Symposium on New Frontiers in Dynamic Spectrum Access, vol.25, no. 3, pp. 517-528, 2007.
5. Deepak K. Tosh, Siba K. Udgata, and Samrat L. Sabat, “Cognitive Radio Parameter Adaptation using Multi-Objective Evolutionary Algorithm” Proceedings of the International Conf. on SocProS 2011, AISC 130, pp. 697–708. Springer India 2012.
6. Thomas warren Rondeau, “Application of artificial intelligence to wireless communications”, Electrical and Computer Engineering; VT; 2007-10-10.
7. Newmann, T.R., “Ph.D Dissertation on Multiple Objective Fitness Functions for Cognitive Ra dio Adaptation”, 2008.
8. Ma, J., Jiang, H., “Optimal Design of Cognitive Radio Wireless Parameter on Non-dominated Neighbor Distribution Genetic Algorithm”, Eighth IEEE/ACIS International Conference on Computer and Information Science (ICIS'09), pp. 97-101, 2009.
9. Yong, L., Hong, J., Qing, H.Y., “Design of Cognitive Radio Wireless Parameters Based on Multi-objective Immune Genetic Algorithm”, WRI International Conference on Communications and Mobile Computing (CMC '09), vol. 1, pp. 92-96, 2009.
10. Pratap, A., Deb, K., Agarwal, S., Meyarivan, T, “A Fast Elitist Non-Dominated Sorting Genetic Algorithm For Multi-Objective Optimization”, 6th International Conference on Parallel Problem Solving from Nature, pp. 849-858, 2000

11. Mohamed Ibnkahla, “Cooperative Cognitive Radio Networks: The Complete Spectrum Cycle”, CRC Press, 2014.
12. C. M. Fonseca and P. J. Fleming, “Genetic Algorithms for Multi-Objective Optimization: Formulation, Discussion and Generalization”, Fifth International Conference on Genetic Algorithms, S.Forrest, Ed. San Mateo, CA: Morgan Kauffman, pp. 416–423, 1993.
13. N. Srinivas and Kalyanmoy Deb., “Multiobjective Optimization Using Nondominated Sorting in Genetic Algorithms”, Evolutionary Computation, 2(3), pp.221- 248, 1994
14. Joong Hoon Kim, G.V. Lokanathan, Zong Woo Geem., “A New Heuristic Optimization Algorithm: Harmony Search”, Research Gate, 2001 sim.sagepub.com/content/76/2/60.short?rss=1&ssource=mfr