Energy Efficient Power Allocation in Cognitive Radio Network Using Hybrid Particle Swarm Optimization

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Abstract: In the field of CR network energy efficiency problem is very important. In this paper, how we can do energy efficient power allocation in orthogonal frequency division multiplexing (OFDM) based CR network by using different algorithm is investigated. Based on PU activity model, number of researchers has proposed a new algorithm for designing energy efficient CR system in terms of sensing and transmission durations under constraints of interference to the PU. In this paper, we present an improved particle swarm optimization (PSO) algorithm to solve the difficult large-scale optimization problem directly. As we know that the original PSO stuck in local optimal that's why an improved version of PSO have been made that combines the chaos, where chaos theory can help PSO search for solutions around the personal and global bests. We have surveyed that the chaos enhance the result of firefly when they both used together that's why to further improve the result we have applied firefly on the result of chaos. The combined name of algorithm is Hybrid Particle swarm optimization with chaos and firefly (HPSOCF). The simulation result in matlab has shown that the proposed algorithm achieve more energy efficiency than other algorithm.

Keywords: *Cognitive radio (CR) network, OFDM, Particle swarm optimization (PSO), energy efficiency, Chaos, Firefly.*

I. INTRODUCTION

Ever present demand for wireless services lead us to realize the need for more resources. But present wireless networks followed the fixed spectrum assignment policy. As a result ISM 2.4 GHz band is generally available for future applications. The unauthorized band access is generally risky as it leads to increased chances of licensed interference and hence leads to degradation of the system performance in these both the licensed and unlicensed bands are now full to their capacity. Current inclination towards uninterrupted association leads wireless technology expensive and limited resource. RF is an important resource and it should be utilized efficiently. In [1] this perspective, FCC allowed spectrum policy task force to perform the changes in the spectrum strategy and they had concluded that the difficulty is the shortage of spectrum and it often becomes a trouble to access the spectrum. In this authorized users given a spectrum have not properly used and there are gaps in the spectrum. These gaps are known as spectrum holes. CR is an adaptive, intelligent radio and network technology that can automatically detect available channels in a wireless spectrum and change transmission parameters enabling more communications to run concurrently and also improve radio operating behaviour. In wireless communication technique frequency band is inadequate resource. Currently, the EM Spectrum electromagnetic spectrum for wireless communication systems follows the permanent allocation strategy. In this strategy, those who are purchasing a given segment of the frequency band obtain the permit for exclusively use of it, in spite of actually not occupying that segment during all instances and in the whole coverage area. This permanent allocation strategy, along with the large growth in wireless communications systems and services has led to spectrum congestion and underutilization at the same time. Due to fixed spectrum sharing or static allocation its utilization is poor. In this paper we have considered an orthogonal frequency division multiplexing (OFDM) based CR network. We mainly focus on the energy efficiency of the cognitive radio network. This paper is divided into number of sections: Section 1: The problem of energy efficiency will be discuss. Section 2: How we can improve the energy efficiency in CR network by using different algorithm for resource allocation in CR network will be discus. Section 3: Proposed algorithm will be discus and the reason behind hybrid of PSO with Chaos and firefly and the simulation result of proposed algorithm will be shown. Section 4: Model and simulation results.

II. SECTION 1

Energy efficiency- Energy efficiency problem is very important in the field of CR network.

Energy consumption is critical in wireless systems, in terms of:

- Cost
- Availability
- Feasibility
- Quality of Service
- Usability
- Robustness

For improving efficiency of spectrum sensing in cognitive radio (CR) systems the authors of [2] have investigated a novel stochastic strategy to spectrum sensing. The problem is formulated as an optimization problem of selecting the optimal sequence of channels to delicately sensing to maximize the obtaining available channels probability and is then finally solved by using a Markov-Chain Monte-Carlo (MCMC) nonparametric approach and are a class of algorithm for sampling from a probability distribution based on constructing a Markov chain that has the desired distribution of its equilibrium distribution. After a number of steps the state of the chain is then used as a sample of the desired distribution. Noticeably improved performance is achieved in terms of overhead and percentage of missed spectrum opportunities, whose quality improves as a function of the number of steps and in this paper the proposed algorithm experimental results shows that it has the potential to achieve, thus making it well suited for use in CR networks. **In 2011 Wen Bin Chien, et al.,** [3] analysed that now days CSS are greatly used because there is a problem when there is a single user used for band sensing. However in CSS a large number of users are not used at every instant so there is a large amount of wastage in terms of energy .To combat this problem DRP and DRM is proposed to reduce the energy and designed an energy saving ideology for CR. It reduces the energy exertion by about 64% compared to previous schemes.

Based on PU activity model, number of researchers has proposed a new algorithm for designing energy efficient CR system in terms of sensing and transmission durations under constraints of interference to the PU (i.e., probability of detection and PU reoccupation probability). The work shows that there is a joint optimal sensing and transmission duration that maximizes the energy efficiency; an iterative suboptimal algorithm was proposed to determine both optimal sensing and transmission durations. The first setup is power allocation to users by using water flow algorithm than population initialization have been done by using Chaos theory than before applying PSO algorithm firefly algorithm have been applied due to the reason discussed in problem formulation.

II. SECTION 2

In paper [4] to maximize the sum rate of the secondary networks without degrading the PU performance the interference constraints are imposed to the secondary network. In future Will focus on the optimization of the sum rate by dealing with the relay amplification factors simultaneously with the transmit power allocation either by deriving an optimal solution or by employing a heuristic approach such as Genetic algorithm (GA), particle swarm optimization and hybrid of PSO with other algorithms. **In 2013 Ahmad alsharoa, et al.** [5] have used the same approach as above but along with GA practical heuristic algorithm based on GA which maximizes the secondary achievable sum rate of a multiple relay selection scheme for TWR-CR system with discrete power distributions. **In 2014 Alsharoa, et al.** [6] introduced and solved a new optimization problem for multiple-input multiple-output two-way relaying operating in underlay cognitive radio networks. **In 2015 Lei Xu, et al.** [7] proposed that hybrid PSO (HPSO) could achieve the improved average weighted sum-rate throughput and satisfy the probabilistic interference constraint condition but HPSO has large computational complexity which would increase the cost of hardware & HPSO is a centralized resource allocation algorithm which needs large feedback overhead. Number of papers has been reviewed for improving energy efficiency in cognitive radio: **In 2015 Lei Xu a, et al.** [8] have worked on the energy-efficient resource allocation problem based on chance-constrained programming for overlay cognitive OFDM system. By using hybrid quantum PSO which includes Quantum PSO (QPSO) and RBF neural network improves the power consumption and also satisfies the outage probability requirement. **In 2015 Mohammed I. M., et al.** [9] concluded that energy harvesting network (EHN) is a trending topic among the recent researches. Moreover, by harvesting energy of RF and renewable sources EHN will enhance energy efficiency. In contemporary research works, EHN is applied to CR technology. Both energy and electromagnetic spectrum efficiently is expected to utilize by energy harvesting cognitive radio network (EHCRN). However, related to technical design EH-CRN is facing enormous challenges. In recent surveys some of those challenges are reviewed. Therefore, the aim of the author was to review EH-CRN research works by focusing the survey perspective on maximizing the network throughput and the implementation models. **In 2015 Meiqin Tang, et al.** [10] proposed, a simultaneous cooperative spectrum sensing and energy harvesting model to improve the transmission performance of the multichannel cognitive radio (CR). The frame structure is divided into sensing slot and transmission slot. In the sensing slot, the secondary user (SU) splits the sub channels into two sub channel sets, one for sensing the primary user (PU) by multichannel cooperative spectrum sensing and the other one for collecting the radio frequency (RF) energy of the PU signal and noise by multichannel energy harvesting. To achieve the sub-optimal solutions to the optimization problems, they have proposed the sub channel allocation algorithm and the joint optimization algorithm of sensing time and transmission power based on the Greedy algorithm and the alternating direction optimization. The stopping criterion of the SU is described, when the PU is not present but the harvested energy is not enough. The simulation results are presented to demonstrate the validity and predominance of our proposed algorithms. **In 2016 Xin Liu, et al.** [11] have investigated the trade-off between utility and energy consumption in OFDM-based CR network. The formulated problem is a large-scale non-convex problem, which is very difficult to solve. In this paper, we present an improved PSO algorithm to solve the difficult large-scale optimization problem directly. Given the weak convergence of the original PSO around local optima, an improved version that combines the chaos theory is proposed in this study, where chaos theory can help PSO search for solutions around the personal and global bests. In addition, for the purpose of accelerating the convergence process when facing with such a large-scale optimization, the original problem is decomposed into a number of small ones by employing the co evolutionary methodology, and then divide-and-conquer strategy is used to avoid producing infeasible solutions. Simulations demonstrate that the proposed coevolution chaotic PSO needs a smaller number of iterations and can achieve more energy efficiency than the other algorithms.

III. SECTION 3

The new proposed algorithm: HPSO-CF (Hybrid of Particle swarm optimization with Chaos and Firefly- In this paper we have considered an orthogonal frequency division multiplexing (OFDM) based CR network. Firstly to maximize the energy efficiency, we have formulated a power allocation problem which maximizes the energy efficiency. As we have considered the base stations (BSs) in the system, the optimization problem become centralized and nonconvex which is hard to solve as they have properties of a non linear programming problem and it may have multiple locally optimal points because of which it can take a lot of time to identify whether the problem has no solution or if the solution is global. It is also hard to transform the nonconvex problem to a convex one. So in this paper, to solve the nonconvex problem we have used PSO (particle swarm optimization) algorithm, which is popular in solving the nonconvex optimization efficiently. PSO algorithms are modern heuristic algorithms based on bird flocking, there is no such theory proof exist which tell that we will get the global optimum by using PSO but the use of PSO by different researcher in solving complicated optimization problems. PSO methods also have been used popularly in wireless networks. For example, PSO is used by Zhao et al. [12] to optimize CR parameters based on the spectrum environments and user needs.

There are number of advantages of PSO along with that there is one main disadvantage of PSO is that it may be stuck in local optimal solution rather than giving the global optimal value when used individually because of its high speed. So, we have combined the Chaos and firefly with PSO to get rid from the drawback of PSO of getting stuck in local value. From literature it has been seen that when chaos is used with PSO which will help PSO search for solutions around the personal and global best and chaos has the denatures of randomness, periodicity and regularity. There is one very good property of Chaotic PSO algorithms is that it can maintain the population differences. Number of researchers has used Chaos theory with PSO for number of applications. Chaotic dynamic is applied on PSO algorithms by Liu et al. [13] they have used the local searching behaviour of chaotic. Fuzzy identification is consider by Coelho and Herrera [14] which have used chaotic Zaslavskii map sequence and efficient Gustafson Kessel clustering to enhances PSO algorithms. To build TS fuzzy model the chaotic PSO algorithm is better one. The author in [15], have enhanced the PSO algorithm with chaotic under the logistic equation in prediction of silicon content in hot metal.

In [16] for a hybrid forecasting model the author has apply PSO algorithm to estimate the unknown parameters in which by chaotic mappings initial values of unknown constants in particle velocity and position equations are generated. As we have seen the compatibility of PSO algorithms with Chaos theory we adopt a chaotic PSO algorithm in this paper.

For energy efficient power allocation Firefly algorithm is used with chaos and firefly due to the reason given in literature**. In 2013 Xin-She Yang, et al.** [17] have analyzed nature-inspired met heuristic algorithms. About five years ago firefly algorithm appeared and its literature has expanded dramatically with diverse applications. By balancing exploration and exploitation they have discussed the optimality associated, which is essential for all metaheuristic algorithms. They concluded that metaheuristics algorithms such as firefly algorithm are better than the optimal intermittent search strategy by comparing it with intermittent search strategy. **In paper: Firefly algorithm with chaos** [18] has been used to increase its global search mobility for robust global optimization. Firefly algorithm (FA) is metaheuristic optimization algorithm which based on the flashing and attraction characteristics of fireflies' mimics the social behaviour of fireflies. With different chaotic maps detailed studies are carried out on benchmark problems. Here, 12 different chaotic maps are utilized to tune the attractive movement of the fireflies in the algorithm. The results show that some chaotic FAs can clearly outperform the standard FA. Particularly the firefly algorithm is used for solving optimization problems which are discrete and continuous. As seen from the recent research many variants of the firefly algorithm have recently been developed so that different optimization problems have been tackling efficiently and fast. In order to improve the randomness when generating new solutions various chaotic maps are used with firefly which will increase the diversity of the population. The aim of this review is to present that the firefly algorithms are enhanced with chaotic maps and described in detail the advantages and pitfalls of the many different chaotic maps. There is one more paper that has used the same combination of algorithms. **A review of chaos-based firefly algorithms the Perspectives and research challenges have been discussed** [19**]** This have been analyzed from different papers that the firefly algorithm perform very well with Chaos and it also enhance the results of firefly when it is use with hybrid of another algorithms. So, in another paper the researcher have used Firefly algorithm with PSO and have seen that firefly algorithm perform very well with PSO. As there are lots of problems which are very complex and individual use of PSO will not give the required or best results that's why it s required to combine the PSO algorithm with another algorithms. From different papers it have seen that when PSO used along with Firefly it will give better results and the drawback of PSO which is that it will stuck in local optima and will not able to give the global optimal results. In proposed algorithm the Firefly and chaos have been applied the chaos is used for initializing the population that on that firefly and PSO algorithm have been applied and it can be seen from the simulation results that the proposed algorithm will improve the results in terms of energy efficiency.

Algorithm	Parameter name	Parameter value
Chaos:	Control parameter (μ)	4
	Lower value of range of each particle (Sa)	0
	Upper value of range of each particle (Ta)	3
Firefly:	Decision variable lower bound (VarMin)	0
	Decision variable upper bound (VarMax)	3
	Maximum number of iterations	10
	Number of fireflies (npop)	40
	Light Absorption Coefficient (gamma)	1
	Attraction Coefficient Base Value (beta)	2
	Mutation Coefficient (alpha)	0.2
	Mutation Coefficient Damping Ratio (alpha_damp)	0.98
	Uniform Mutation Range (delta)	0.05*(VarMax-VarMin)
PSO	C1	1
	C2	1
	Inertia weight	0.9
	Max iteration	1000
	Number of subcarrier	32
	Total transmit power (P_tot)	8mW, 45mW
	Number of secondary radios (N)	200
	Area	1000m*1000m
	Background noise (n)	5mW

IV. SECTION 4

In this paper we have consider one Primary user (PU) and 200 Secondary users (SU's). The secondary transmitters are allowed to use the licensed spectrum band of a PU. The network system contain one primary base station (BS) and one secondary BS to handle PU network and secondary network respectively. The number of iterations is 1000.

The essential Procedure of applying proposed optimization algorithm:

In this firstly the initialization of population has been done by chaos than after that firefly algorithm has been applied so that the PSO will not stuck in local optimum. In chaos the population is initialized by using equation CurrentPosition=Sa+(Ta-Sa)*Zn" where Sa and Ta is the value range of particles.

Step 1: Initialization of population by using chaos equation "CurrentPosition=Sa+(Ta-Sa) * Zn" where Sa and Ta is the value range of particles.

Step 2: Evaluate the fitness function of each particle.

Step 3: Optimize the global best value by using Firefly algorithm.

Step 4: Apply the PSO on the result of Firefly to improve the results.

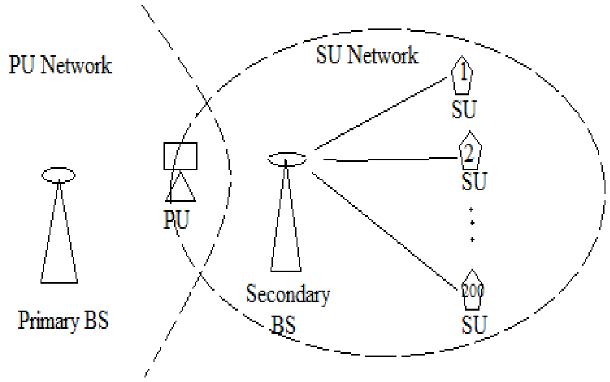

Fig.1: The network system

V. PERFORMANCE PARAMETER

Comparative analysis1: In this comparative analysis of existing algorithm and proposed algorithm is given in terms of energy efficiency when the power allocated is 8mW.

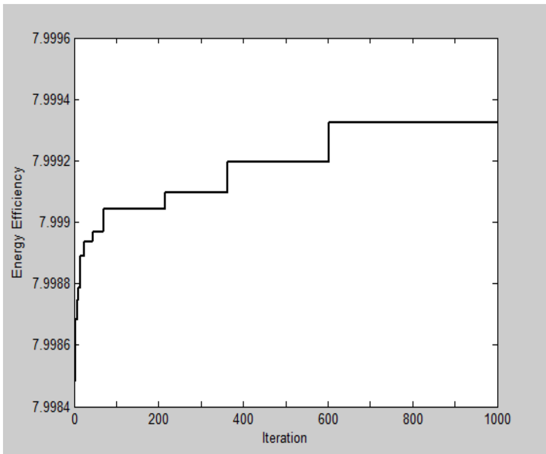

Fig.2: Energy Efficiency when allotted power is 8mW

Comparative analysis1: In this comparative analysis of existing algorithm and proposed algorithm is given in terms of energy efficiency.

Parameter	Values	Existing work (CCPSO)	Proposed work (HPSOCF)
Energy Efficiency	Best	7.8652	7.9993
	Worst	7.8652	7.9985
	Average	7.8652	7.9992

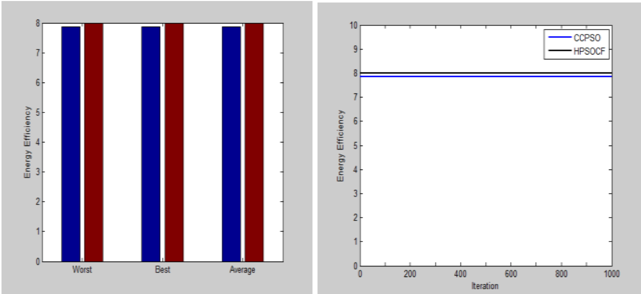

Fig.4 Comparison results of CCPSO and HPSOCF when allocated power is 8mW

By increase in number of iterations the results have been improved in terms of energy efficiency. Simulation results show that proposed solution gives good performance in terms of energy efficiency by 1.65 % than from the existing algorithm used for the same purpose. In this work when 8mW of power is allocated out of which we are getting 7.996 of energy efficiency. Which show that the proposed algorithm is better.

Comparative analysis2: In this comparative analysis of existing algorithm and proposed algorithm is given in terms of energy efficiency when the power allocated is 45mW.

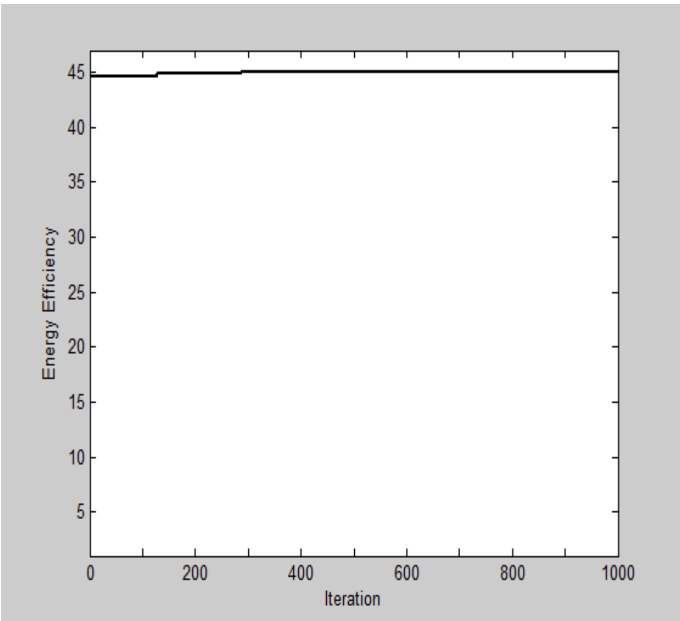

Fig.5 Energy efficiency when power allotted is 45mW

Comparative table2:

Parameter	Values	Existing work (CCPSO)	Proposed work (HPSOCF)
Energy Efficiency	Best	41.0927	44.9998
	Worst	41.0927	44.3501
	Average	41.0927	44.9039

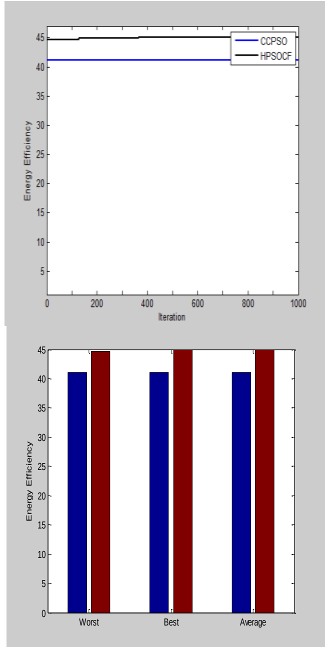

Fig.6 Comparison results of CCPSO and HPSOCF when allocated power is 45mW

Another case we have taken 45nW of total power and have seen from the comparison results from the previous algorithm that proposed algorithm give better result by 9.50%. In proposed algorithm we have achieved energy efficiency of 44.9998. Figure 2 show the matlab simulation results of energy consumption which show that energy consumption vary for every iterations it can be seen that the energy consumption is reducing by increase in number of iterations for this result we have taken number of iterations equal to 1000. Figure 3 and Figure 5 show that the energy efficiency which is varying by the number of iterations and for this also we have taken 1000 number of iterations. The result of figure 4 and Figure 6 of energy efficiency versus iterations show that the energy efficiency or saved energy increased by using the proposed algorithm which can be easily seen by the two comparison graphs.

VI. CONCLUSION

In this paper a new algorithm is proposed which is Hybrid Particle Swarm optimization with firefly and chaos (HPSOCF). As when PSO individually have used it will stuck in local optima that's why a new algorithm is proposed. From previous research work from different researcher this have been seen that the PSO will give improved result when used with firefly and firefly is also work very well with chaos. It is observed that the proposed algorithm is actually capable of quickly achieving energy efficient solutions. Simulation results verify that HPSOCF not only improves the energy consumption, but also satisfies the energy efficiency. In this paper firstly we have done power allocation by using water flow algorithm than population initialization has been done by using chaos theory equation. On the result of chaos initialization have applied firefly algorithm than PSO algorithm is applied on it. We have concluded that we get improved result than from the previous paper that have used the hybrid PSO with some other technique and by increase in the number of iterations we get improved result in terms of both energy consumption and energy efficiency. When we have allocated 8mW of total power we are getting efficiency of 7.9996 and when 45mW of power is allocated than we get 44.9998 this is 9.5% better than the energy efficiency we get from the previous algorithms.

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