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QOS Parameter Optimization For Cognitive Radio Networks

[I]Vinutha.P, [II]Sutha.J
[I,II]Sethu Institute of Technlogy, Virudhunagar, India

Abstract
The drastic developments in the field of wireless communication have led to the problem of spectrum scarcity which is becoming more worsened day by day. Cognitive radio (CR) has been to overcome spectrum scarcity problem. CR is self-configurable wireless communication system that has the capability to measure un-used portions of the existing wireless spectrum (so-called white spaces) and adapts the radio's operating parameters to operate in these unused portions in a manner that limits interference with other devices by environmental sensing and quality of service needs. One of the crucial parts of the CR device is decision making of selecting appropriate communication parameters for self-configuration. In this paper, simulated annealing (SA) with multi-objective function is used for CR optimization. SA is a stochastic global optimization technique that distinguishes between different local optima.SA has been used to meet the user's QOS needs i.e. optimal global minimum, minimum transmission power, maximum throughput and minimum BER. The results presented indicate that SA technique is efficient for providing a better optimal solution for CR optimization.

Keywords
CognitiveRadio, Simulated annealing, Fitness function, optimization, Multi-objective function

I Introduction

Radio frequency spectrum responsible for all transmissions is a natural scanty resource. Thus to regulate and manage, FCC has cleft the spectrum into licensed and unlicensed part where the users of licensed part are said to be the primary or legitimate user and unlicensed part as secondary users. The rapid growth of wireless technologies has made spectrum scarcity a serious problem as more and more wireless applications compete for very little spectrum. The spectrum usage is concentrated on certain portions of the spectrum whereas a significant portion of the spectrum remains unutilized. Hence, to improve the spectrum utilization and provide efficient communication the concept of Cognitive Radio technology is introduced [1-3].

Cognitive radio has the ability to automatically detect the unused spectrum (white spaces) using spectrum sensing techniques such as energy-detection, cyclostationarity-based detection, waveform-based & so on. Once the white spaces are detected they can be used by the resources, but as different users uses the same frequency band for distinct purpose, it is vital to provide interference control and to fulfil their QOS requirements. CR devices are equipped with an intelligence to sense their environment, learn it and adapt in a way that provides optimized service to fulfil user needs.

Optimization of CR system has been done using evolutionary techniques like genetic algorithm (GA) and ant colony optimization (ACO) [4–7].The optimization of CR system has been accomplished using GA for three objectives: minimum transmit power, minimum BER and maximum throughput [4, 5] and five objectives: minimum transmit power, minimum BER, maximum throughput, minimum interference and maximum spectral efficiency, has also been done [6]. The three objective functions have also been accomplished using ACO [7].

Simulated annealing (SA) is a process of cooling a system where it's possible energies corresponds to the values of objective function being minimized. The benefit of using a SA is its very minimal structure that makes it straightforward and simple. While compared with other evolutionary techniques, it is found to be less greedy i.e. it doesn't struck into local optima.

In this paper, SA has been used to emulate the optimization of CR system. SA is found to be more useful for black-box type problems as it shows good asymptotic convergence properties [9]. SA finds its application in many engineering disciplines. Here, SA has been used to determine the optimal set of radio's transmission parameter to meet user's QOS.

Organization of the paper is as follows: In the section II simulated annealing process is described. Section III includes the various environment and transmission parameters of CR system and the objectives to be fulfilled. Section IV explains the fitness evolution strategy for CR system. Section V consists of the results obtained after applying SA to CR. Conclusion and future enhancement is drawn finally.

II Simulated Annealing Process

Simulated annealing (SA) is one among the popularmetaheuristic algorithm that is found to be effective for combinatorial optimization problems [8-13]. In our work this algorithm has been used for basic search since it allows the use of smaller number of parameters sets while compared to other techniques. The fundamental idea of SA is the analogy in which a liquid cools and freezes into a crystalline structure. When the liquids are at high temperature their molecules moves freely whereas at low temperature the freedom of movement is lost and it gets solidify. Molecules in the crystalline structure will be in minimum energy state. And this can be accomplished only if the liquid is cooled very slowly. The key idea behind SA is that the steps involved in an iterative improvement algorithm are similar to the rearrangement of molecules in a liquid that occurs as it is cooled, molecules energy corresponds to the objective function that is being optimized using the algorithm. In this fashion, SA tries to achieve a global optimum by slowly converging to final solution, making downwards moves with occasional upwards moves as a result leading to a global optimum. The functional diagram of SA algorithm is shown in Fig.1.

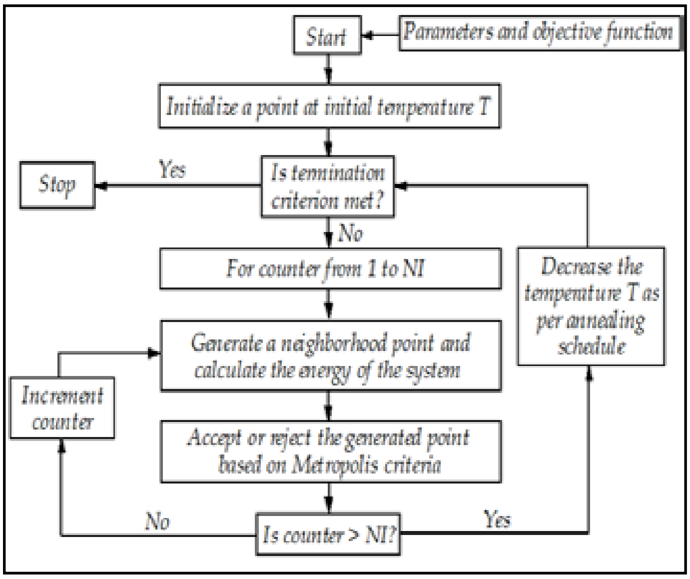

Fig. 1 Functional diagram of simulated annealing algorithm

Starting from a random position in the search space the next position is chosen at an arbitrary location within distance of a jump proportional to a temperature parameter. Initially, the temperature is set to maximum. The probability of accepting the new location as a new starting point is proportional to the improvement in utility. Each iteration of the search also leads to decrease in temperature. The algorithm stops when the temperature drops below a certain threshold. The process of "heating" of the search space and its controlled cooling can be performed iteratively and is called "reheating" [14].

III Cognitive Radio Parameters and Objectives

In CR Network systems, the environmental parameters are defined as inputs to the CR system whereas the transmission parameters will be the system outputs. The relationships between the environmental and transmission parameters are formed by mathematical equations that are further defined as objective functions. As the cognitive radio systems senses the environment and reconfigure its transmission parameters optimally to satisfy the objectives and efficiently utilize the available spectrum band choosing of the best possible set of parameters is most important as it largely affect the accuracy and efficiency of CR. This can be done by determining the appropriate parameters and objectives for the system.

1. Transmission Parameters

Transmission parameters act as the decision variables for the CR system, so it must be well-defined before developing fitness functions for various objectives. Table 1 shows the list of transmission parameters used in our work

TABLE 1 Transmission parameters

PARAMETER NAME	DESCRIPTION
Transmit power	Raw Power Transmission
Modulation Type	Type of the modulation scheme used
Modulation level	No. of symbols used for given modulation scheme
Symbol rate	No. of symbols per second
Packet size	Size of the packet

2. Environmental Parameters

Environmental parameters are the sensed information that provides knowledge about the surrounding environment's characteristic to the CR system. This helps in decision making process. The environmental parameters used here are: Data rate, Power consumption, Spectral efficiency, occupied band, Bit error and Packet error.

3. Cognitive Radio Objectives

Certain objectives needs to be fulfilled by the CR system are stated here. In this work, we will define the following objective functions in order to guide the system to an optimal state. Table 2 depicts the objectives used in this work.

TABLE 2 CR User's Objectives

OBJECTIVES	DESCRIPTION
Optimum global solution	Provides an optimal solution
Minimize power consumption	Decrease the amount of power consumed by the system
Maximize throughput	Increase the overall data throughput transmitted by the radio
Minimize BER	Improve the overall BER of the transmission environment

TABLE 3 Parameters range

PARAMETERS	RANGE
Transmit power	1 to 30 dB
Modulation Type	BPSK, BFSK, MPSK, MQAM, QSK, GMSK
Modulation level	2, 4, 8, 16, 32, 64
Symbol rate	1e4: 1e3 : 1.28e5
Packet size	256 : 16 :2048

The search space is created by combining the transmission and environmental parameters along with thedefined objective functions. The range of the input transmission parameter is given in Table 3.The combination of these parameters with the objective function would lead to a large number of solutions which forms the search space.

IV. Fitness Evolution for Cognitive Radio System

In this paper, four objective functions have been formulated to accomplish the four distinct objectives- optimal Global Minimum, Minimum power, Maximum Throughput and Minimum BER. Their respective objective function is given below:

The fitness function of minimizing power consumption is given as:

$f_{min - power} = P * Rs * K$

Where, P is the transmitting power, Rs is the symbol rate, K is modulation index (K =2 for MQAM and BPSK and K=1 for remaining all).

The fitness function for maximizing data rate is given as:

$f_{Max-Throughput} = Rs * \log2 (M)$

Where Rs is the symbol rate, M is modulation index.

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The fitness function for minimizing BER is given as:
f Min - BER = qfunc (sqrt (2.0*ebno)) forBPSK & QPSK
f Min- BER=qfunc (sqrt (ebno)) for BFSK
f Min- BER=qfunc ((2*log2 (M)*ebno) * sin (pi/M)) for MPSK
f Min- BER = cef * erfc (sqrt (s)) for MQAM
f Min- BER = qfunc (sqrt (2.0*alpha*ebno)) for GMSK
Where,
ebno=CbN+10*log10 (Bw/Rb)
The fitness function for minimizing Packet erroris given as:
f Min- PER=1.0-(1.0-BER)^Ps
Where, Psis Packet size.

The fitness function foroccupied bandwidthis given as:
f Bt=(1+r)*Rb forBPSK& FPSK
f Bt= ((1+r))/log2(M)) *Rb for MPSK&MQAM
f Bt= ((1+r))/2) *Rb for QPSK
f Bt=r*Rb for GMSK
Where, r isroll off factor and Rbis bitrate.

The fitness function formaximizing Spectral efficiencyis given as:
f Max - spectraleff = Rb/BW
BW=1e6
Where, Rbis bit rate,
BWis band width.
Now as we have multiple objectives to be fulfilled, therefore the weighted sum approach has been used in this SA based CR system. The weighted sum approach allows us to combine the single objective functions into one aggregate multiple objective functions.

fitness value=ws(1)*fMax-Throughput+ws(2)*fMin-Power +ws(3)*fMax-spectraleff +ws(4)*fBt+ws(5)* fMin-BER+ws(6)* fMin-PER

Table 4 Weighting factors

Scenarios	Weight Factors [w1 w2 w3 w4 w5 w6]
Global minimum	[0.166 0.166 0.166 0.166 0.166 0.166]
Minimizing Power Consumption	[0.08 0.6 0.08 0.08 0.08 0.08]
Minimizing BER	[0.45 0.05 0.2 0.2 0.05 0.05]
Maximizing Throughput	[0.1 0.1 0.1 0.1 0.4 0.2]

The weighting values, w1, w2, w3, w4, w5 and w6 determine the search direction for the optimizing algorithm. We have defined four weight vectors representing common scenarios a cognitive may be placed in. each weight vector listed in Table 4 emphasizes different objectives that lead the algorithm using this fitness function to develop a solution that relate to a specific objective.

V. Simulation Results

Simulated annealing has been applied for a single carrier CR system to fulfil various objectives using Matlab.

Table 5 Results obtained by SA

Scenarios	Transmit Power (P)	Modulation Type (M)	Modulation Level	Symbol Rate (RS)	Pkt size	Final Fitness Score
Optimum global solution	11.6	BFSK	64	126.00 Kbs	1440	0.044459
Minimizing Power Consumption	1.0	BPSK	64	127.00 Kbs	352	0.028515
Maximum Throughput	1.0	BPSK	64	128.00 Kbs	256	0.0047017
Minimum BER	4.4	BPSK	64	128.00 Kbs	1344	0.016404

In this section, only four parameters namely global minimum, minimum transmit power, minimum bit error rate (BER) and maximum throughput have been optimized using SA. These four parameters are dependent on two input transmission parameters-Transmitted power (P) and Modulation index (M). The transmitted power ranges from 1 to 30 db. We have used BPSK, BFSK, MPSK, MQAM, QSK, GMSK modulation scheme, with number of symbols ranging from 1e4: 1e3: 1.28e5. The number of iteration in SA is kept as 5,000. The annealing function used is fast annealing, which take random steps with size proportional to temperature. Reannealing interval and initial temperature are kept to be 500, with exponential temperature update function.

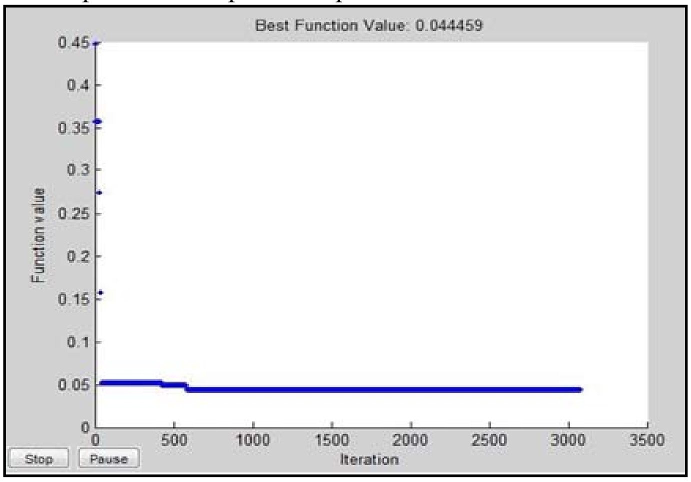

Fig. 2 Convergence characteristics for Optimal Global Minimum

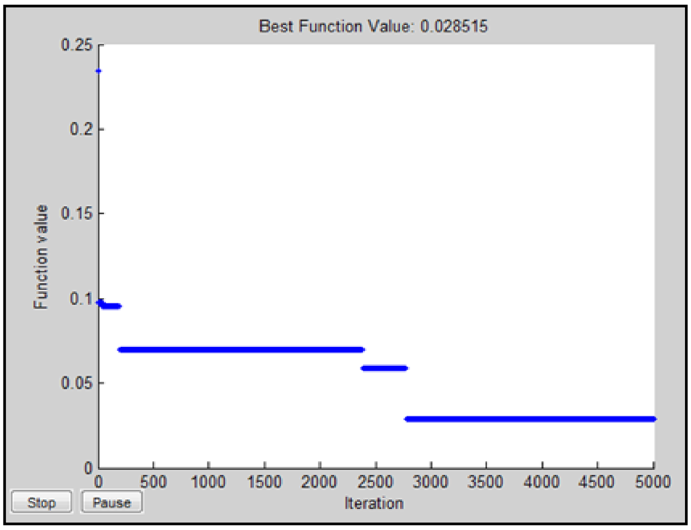

Fig. 3 Convergence characteristics for Minimum Power

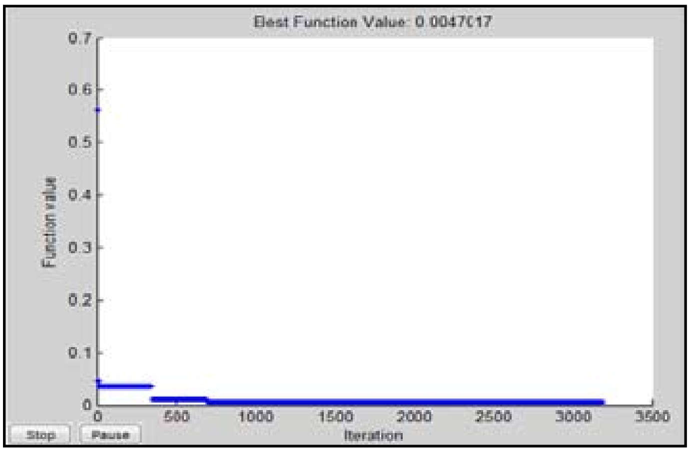

Fig.4 Convergence characteristics for maximum throughput

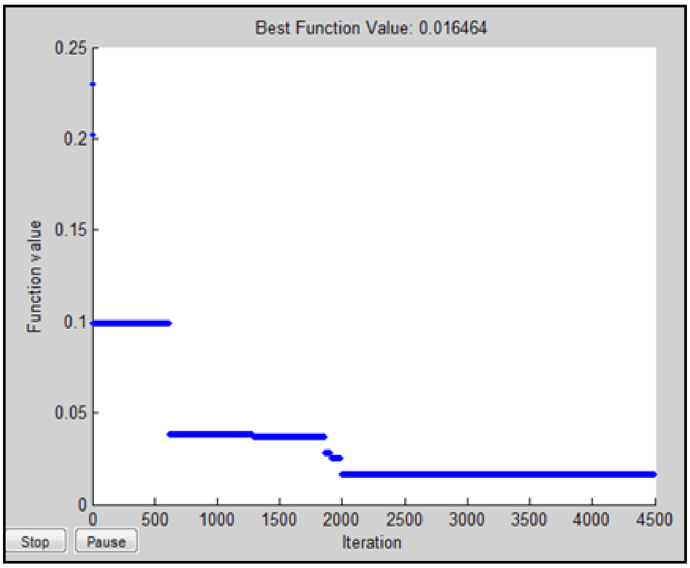

Fig. 5 Convergence characteristics for minimum BER

VI. Conclusion and Future Enhancement

In this paper, SA has been proposed for optimizing CR System. Different transmission parameters of the CR system have been optimized to satisfy various objectives under the environmental constraints. Simulation results obtained after implementation of SA to the CR system provides the optimal set of solutions and is found to be efficient.

With the explosion of wireless voice and data traffic, we must be willing to embrace this highly innovative approach to optimizing spectrum access and utilization. The proposed model considers a few parameters only, in order to maintain the simplicity in the research. These are the data rate, the modulation scheme, power and BER etc. Some other parameters can be introduced in the research at the advanced stages.

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Author Biographies

Vinutha.P is currently pursuing her Master degree in computer and communication engineering in sethu institute of technology, Virdhunagar. She did her B.Tech from sethu institute of technology, Virdhunagar in information technology in 2012. Her research interests are cognitive radio and optimization techniques.

Dr. J. Suthaispresently working as Professor and Head of Computer Science and Engineering of Sethu Institute of Technology, Virudhunagar. She did her Bachelor's degree in Computer Science and Engineering in the year 1991 from Madurai Kamaraj University, andobtained hermaster's degree in Computer Science Engineering in the year 2000 from Madurai Kamaraj University, Madurai and completed Ph.D. Program in Anna University, Chennai in the year 2008.She has published eight papers in International Journals, six papers in International conferences and twelve papers in national conferences.She is having over 16 years of teaching experience and 3 years industrial experience.She has guided several Ph.D. scholars. Her field of specialization is Image Processing and Artificial Intelligence.