Survey on Bio-Inspired Approaches for Allocation of Spectrum in Cognitive Radio Sensor Networks

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Abstract: ***Cognitive radio (CR) is a viable technology for tackling spectrum shortages and increasing the use of radio spectrum that is currently underused. This study looks at how multi-objective optimization methods are used for power and spectrum allocations in cognitive radio networks. There are a lot of performance criteria to consider. Spectrum allocation involves several multi-objective optimization (MOOP) problems, such as maximizing throughput, improving network efficiency, and reducing the interference between primary and secondary users. It is impossible to attain with a single-objective optimization strategy. For accomplishing contested multi-objective goals, several bio-inspired techniques such as (PSO, GA, NSGA-II, and ACO) are applied.***

Keywords: Multi-objective optimization, maximize throughput, spectrum utilization

1. Introduction

Increased demand for wireless devices has resulted in spectrum scarcity in recent years. As we all know, the radio spectrum is a limited resource, so making effective use of it is a major challenge in the current situation. Cognitive radio networks are a promising technique for solving spectrum shortages and maximizing unused spectrum. Primary users (PUs) and secondary users (SUs) are the two types of users in cognitive radio networks. In a wireless network, spectrum utilization varies spatially. There are various parts to the spectrum band. Spectrum hole refers to the portion of the spectrum that is not used by the principal user during a given time interval. Those unused spectrum holes are employed by secondary users in cognition technology for effective radio spectrum usage.

In a cognitive radio network, spectrum allocation is critical. Various performance attributes draw attention for spectrum allocation and spectrum management such as higher spectral efficiency [1], maximized cognitive network throughput, lower latency, better network capacity, higher network efficiency, greater convergence level, andachieving QoS, fairness [1]. These are conflicting objectives are considered multi-objective optimization. The above objective cannot be achieved through conventional single-objective optimization. Different bio-inspired algorithms are mostly used for exploring multi-objective optimization.

a) Cognitive Radio Network

Cognitive radio (CR) is a wireless communication technology that is conscious of its surroundings. It makesoptimal use of the radio spectrum and delivers extremely dependable communication whenever and wherever it is required. Spectrum holes are required for CR to work. A spectrum hole is a band or sub-band of frequencies that is not fully exploited by the primary user at any one time, allowing secondary users to exploit the underutilized spectrum hole [9]. Dynamic spectrum management (DSM) is the task of assigning available spectrum holes to CR units according to environmental constraints [22]. There are two approaches to solving this problem centralized and decentralized. The DSM subsystem chooses a common spectrum hole between them and operates on that band as long as it is available [22].If the primary user required that spectrum band, The CR unit must stop transmission and try to find another common spectrum hole [22]. This work is challenging and practically not possible to solve in real-time. These conflicting objectives carefully balance between overall performance in CR networks for allocation, management, and utilization of spectrum.

b) Related Works

Spectrum allocation in CRN plays an important role in wireless communication, for spectrum allocation different types of a single objective, multi-objective optimization algorithms are used for achieving desire objectives while satisfying different network performance criteria and SINR constraints while overcoming the interference between PUs and Sus [10].

In this survey paper, we have reviewed different MOOP for exploring several network performance criteria. These multiple conflicting objectives should be carefully balanced between all the performance objectives. In conventional single objective optimization always give importance to only one objective while neglecting other objectives, so in this paper, we have surveyed several bio-inspired multi-objective optimization algorithms for spectrum allocation. Authors of [1], [2], [3], [5], [7] [21] discussed multi-objective optimization algorithms such as NSGA-II,PSO,GA for power control or sspectrum allocation, energy efficiency, fairness, and spectrum utilization. Authors in [5], [8] use the PSO and GA bio-inspired algorithm for the dynamic resource allocation model as a constrained optimization problem [7]. It also improves the sspectrum homogeneity and heterogeneity, communication overhead and computation communication overhead, and computation complexity.

2. Spectrum Allocation in CRN

This paper reviewed various conflicting objective and performance attributes that affect the designing and implementation of CR network spectrum allocation [1].There will be a careful balance between overall objectives for getting better performance.CR network attain the desired energy efficiency, effective spectrum utilization, fairness, QoS assurance, power control and reduces interference among the primary user and secondary user, throughput maximization [2]. Energy efficiency decides how efficiently energy and power are consumed for data transmission [21]. Spectrum utilization decides how limited the spectrum channel assign for spectrum assignment for both PU and SU [21]. Fairness means how equally the resources of a CR network are shared with the cognitive user [2], [22]. QoS is also an important parameter in CRN to decide authorized users and unauthorized users. It is necessary to maximize the Throughput for the overall wireless network for reducing interference among users. The network efficiency is always inversely proportional to the interference in the network. More network efficiency results in less interference in a network.

a) Dynamic Multi-objective Approaches for Spectrum Allocation in CRN

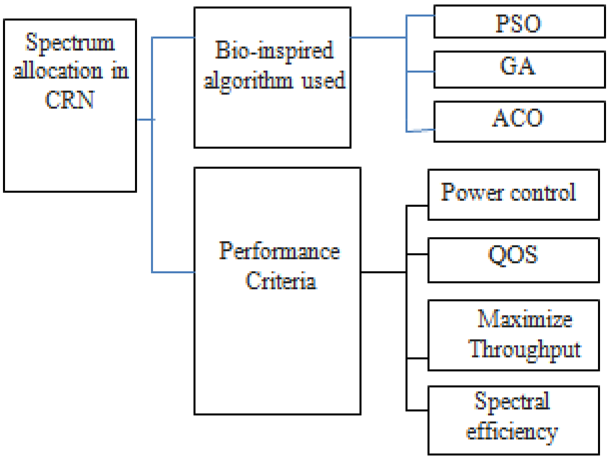

Figure 1: MOOP Approaches and Performance criteria for spectrum allocation

This paper is concerned about various multiple conflicting objectives achieved through several multi-objective optimization algorithms. This paper surveyed multiple bio-inspired algorithms such as PSO, NSGA-II, evolutionary algorithm, cuckoo search algorithm, ant colony optimization, NSGA based on reinforcement learning combining features of the evolutionary algorithm used for spectrum allocation in CRN. Optimal spectrum and power allocation can also be achieved as a multi-objective using an evolutionary algorithm for resource allocation. This paper also reviews all the bio-inspired algorithms and compares GA, PSO, and ACO for getting better convergence rate, accuracy, network efficiency, and spectrum utilization [4].It maximizes end-to-end throughput and simultaneously achieves the maximum Spectrum utilization [5]. Every proposed multi-objective approach has better accuracy in comparison to others and some limitations.

b) Spectrum Allocation based on Optimization Criteria

The bio-inspired algorithms have several properties like independence, adjustment, and ease of use intelligence mostly desirable for spectrum allocation in CRNs, But there are performance attributes considered for spectrum allocation such as energy efficiency, maximize throughput, QoS, and avoid interference, Fairness, Hand-off reduction. Energy efficiency is mainly required for an increased lifetime of the network [11]. 1) Maximum efficiency cannot achieve through minimum energy efficiency.2) for resource allocation maximize throughput is necessary. 3) QoS assurance is necessary for maximum energy efficiency and spectral efficiency. 4) Interference avoidance mainly improves the performance of primary users and secondary users.4) Hand-off reduction also plays a vital role in multi-objective optimization.

Table 1: Summary of literature survey based on performance criteria

Reference	Spectrum utilization	Network Efficiency	Throughput Maximization	QoS Achievement	Energy efficiency	Fairness Assurance	Power allocation
[1]	✓	✓	✓	✓			
[2]			✓	✓	✓	✓	✓
[3]			✓		✓		
[4]	✓					✓	
[5]	✓	✓					

[6]	✓					✓	
[7]	✓					✓	
[8]	✓		✓				
[9]		✓	✓				
[10]			✓				
[11]		✓	✓	✓		✓	
[12]			✓			✓	
[13]	✓		✓				
[14]	✓			✓			
[15]	✓				✓	✓	
[16]	✓	✓					
[17]			✓			✓	
[18]	✓	✓	✓			✓	
[19]	✓						✓

c) Challenges, Issues and Future scope for spectrum Allocation in CRN

In this paper, we have surveyed different multi-objective optimization algorithms most of which are Bio-inspired. Multi-objective optimization problems always optimize one or more conflicting objectives simultaneously. In this survey we have found several methods for spectrum allocation in CRNs based on the following aspects i)Improved spectrum efficiency ii)Fairness among cognitive users iii) improve network capacity iv)reduce cost and complexity v) QoS assurance vi)maximize throughput vi) lessen the interference among PU and SU efficiency. In the below table we have explored different problems addressed and the type of bio-inspired algorithm used in different research work for spectrum allocation, multi-objective optimization achieved and some limitation found in our survey.

Table II

Survey	The problem addressed and various types of bio-inspired algorithms used	Multi-objective resource allocation achieved	Limitation	Publication year
[1]	This paper address the spectrum Allocation Problem related to network capacity and spectrum efficiency are two objectives are achieved through MOO (Modified version of NSGA-II. which combines the feature of Evolutionary Algorithm and Machine Learning)	network capacity and spectrum efficiency	This paper does not focus on maximizing throughput, QoS assurance, and fairness	2020
[2], [21]	The proposed approach has a better convergence level and convergence rate which cannot be achieved through single objective optimization	pure power control or Spectrum allocation, energy efficiency, fairness, and spectrum utilization	Maximize Throughput	2020
[3]	This paper focuses on the Average capacity of a user and Max-sum-Reward. The objective can be achieved using MODE and NSGA-II.	Maximize CRN throughput and also reduce interference among PU &SU.	pure power control or Spectrum allocation, energy efficiency, fairness, QoS assurance spectrum utilization	2020
[4]	To solve the discrete Optimisation problem of CRN for spectrum Allocation, The new methodology used is the Binary Adaptive Cuckoo Search Algorithm.	Maximize the network benefit and fairness between the users	power control	2019
[5]	This paper conveys the Spectrum Allocation problem concerning both Spectrum utilization and network throughput in the CRN-based IoT. The proposed methodology is used for Spectrum Allocation is GA&NSGA-II for effective utilization of Spectrum.	Spectrum utilization and network throughput	energy efficiency, fairness, QoS assurance	2018
[6]	The proposed work maximized resource utilization while minimizing interference and provided guaranteed fairness among users in a Femtocell LTE network. ii. In this paper, it uses NSGA-ii. compare with ACO to solve	resource utilization, fairness	network throughput, QoS assurance	2018
[7]	i.This paper formulates a dynamic resource allocation model as a constrained optimization problem. ii. The proposed PSO scheme achieve energy-saving demand	maximize the overall secondary capacity, provide fairness among Sus and maximize the objective function simultaneously	network throughput, QoS assurance	2018
[8]	i. This work gives more importance to maximizing cluster throughput but minimizes communication Delay. ii. It also improves the Spectrum homogeneity and heterogeneity, Communication overhead, and computation complexity. iii. The above objective can achieve through PSO Algorithm.	maximize cluster throughput	QoS assurance, fairness, pure power control	2018

[9]	This work provides a study on convergence rate, solution diversity, and station load ii. This work uses the multi-objective technique, MOPSO and MOCFO compared with NSGA-II	Convergence rate vs network throughput	resource utilization, fairness, QoS assurance	2017
[10]	This work describes constrained resource allocation problems arising in spectrum access in cognitive radio networks as well as other multi-objective constraints	Maximization of usage by the Sus and minimization interface to the Pus.	network throughput, QoS assurance	2016
[11]	This paper surveys recent technology used in resource allocation scheme	performance criteria, energy efficiency, QoS assurance, fairness, and priority consideration	Power control	2015
[12]	i. This paper describes efficient power allocation and reduce interference	Power allocation, interference among cognitive users, faster convergence rate, and low complexity	Fairness	2015
[13]	To overcome different limitations in CRNs like feedback delays, estimation errors, quantization, reducing interference in PUs error	optimal solution with low complexity	Power control, QoS assurance	2013
[14]	i. This paper focuses on network management and dynamic spectrum availability ii. This paper describes critical challenges in designing and optimization of CRNs by using two bio-inspired techniques(PSO, ACO)	QoS assurance, dynamic spectrum availability	energy efficiency, fairness	2012
[15]	i. his paper solves discrete multi-objective optimization problems. ii. Non-dominated sorting quantum particle swarm optimization	i.it solve the multi-objective optimization problem ii. Fairness, spectrum utilization and QoS assurance	energy efficiency, power control	2012
[16]	To overcome the spectrum allocation problem in CRNs a new type of algorithm is used chemical reaction optimization	Fairness, spectrum utilization, improved spatial diversity, and reduce interference can be achieved through the proposed algorithm	QoS assurance, maximize throughput	2013
[17]	This paper describes the proposed genetic algorithm scheme is more efficient for spectrum allocation	The algorithm gives a better convergence rate and good performance and minimizes power consumption	Fairness, spectrum utilization,	2012
[18]	This paper mainly focuses on how to share the available spectrum bands which are detected and unoccupied by the primary user among the co-existing users.	Channel assignment, reduce interference and maximize throughput, spectrum efficiency	Fairness, QoS assurance	2010
[19]	Power Control and Channel Allocation in Cognitive Radio Networks with Primary Users' Cooperation	performance gain in terms of uplink and downlink	QoS assurance, maximize throughput, Fairness, spectrum utilization,	2009

3. Conclusion

In this study, we look at a variety of resource allocation algorithms, practically all of which are bio-inspired (NSGA-II, PSO, GA, and ACO). The single objective optimization will not be able to achieve all of the objectives. As a result, the research is primarily concerned with multi-objective optimization. The study identifies a number of performance goals, including energy efficiency, throughput maximisation, QoS assurance, interference avoidance, fairness, priority consideration, and hand-off minimization. Nevertheless, some of the papers focus primarily on pure power control or spectrum allocation.

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