REVIEW ON RESOURCE ALLOCATION MECHANISMS IN COGNITIVE RADIO

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ABSTRACT

This paper focuses on the allocation of channel resources in cognitive radio system. Here, Cognitive (RRM) technology is envisaged to solve the problems in wireless networks resulting from the limited available spectrum. RRM developmental growth is high in advanced generations .Moreover, this paper focus on proposing an improved version of the recently introduced optimization algorithm called as GSO to solve the resource allocation problem more effectively. Furthermore, review of radio resource management efforts reported in the literature, the primary contributions reside on optimizing the resource utilization and allocation principles. Hence, the review outcomes are summarized in Table I in the perspective of optimization problem. In research gaps, distributed allocation, Topology discovery, Spectrum access and coordination, evolutionary and learning have been discussed. This paper also discusses the system model of Resource Allocation for OFDM-Based Cognitive Radio Networks.

Keywords: Cognitive Radio, OFDM, Resource, Allocation, Optimization, GSO

I. INTRODUCTION

The demand for multimedia communications, which operate at increased levels of speed using extremely large-sized wireless mobile community, has become very vast. The optimized smart grid is developed to reduce the power consumption in base stations [1]. Video traffic associated with the fixed as well as the mobile networks create problem in allocating the wireless resource [2]. So, the development of Cognitive Radio Resource Management (RRM) is phenomenal in sensor networks [7]. In case of the conventional cognitive radio (CR), the primary users lack the information regarding the secondary users. On the contrary, the secondary user will be always cautious about its operation that it never interrupts the primary users' functionality. The secondary users make use of sensing for satisfying this need. For the most part, the sensing methodology that is relative to the CR literature involves the determination of a spectrum's vacancy or usability [26]. For new generation of wireless communication, 1000 times increased mobile data volume per unit area with 10–100 times enlarged user data rate [8] is foreseen in different fields, such as healthcare, smart metering, and security [3]. Therefore, the main objective of RRM is to share the available and limited radio spectrum between users efficiently with secured Quality of Service (QoS) and high speed data transmission. It includes Dynamic RRM, Static RRM and Inter-cell RRM [6].

RRM developmental growth is high in advanced generations. The Second generation like GSM is replaced by third generation system and Long Term Evolution (LTE) network. LTE network is evolved as a technology in wireless communication, rendering extremely fast data transmission in case of mobile phones as well as the data terminals [16]. For achieving better coverage, LTE-Advanced (LTE-A) is deployed in [10]. Enhancing the efficiency and reducing the congestion of the random access channel of LTE-A [18] is quite challenging. For retrieving the challenge, third generation partnership project introduced the Access class Barring (ACB) scheme [19]. An innovative approach is used to assess the performance that an LTE system offers. For having control over the QOS, two strategies that offer admission control are developed and assessed using Random Waypoint Mobility model [20]. The first strategy is for ensuring QOS that corresponds to non-real time as well as real time calls. The second strategy includes the fair way of resource sharing in non-real time calls [15]. So, for simulation, a number of tools and programs have been developed [17]- Matlab, Simulink, Network simulator 2 and 3, OPNET models, NPSW [16], Dynamic Simulation program [9], Ares [11]. The simulation functions include admission control [12], handover control [13], Pack scheduling [14], power control, and congestion control. Along with these tools, many algorithms are developed for better optimization of radio resource allocation. These algorithms aim at exploiting the cognitive facilities of the network at the maximum extent [21]. The RRM that exploit the cognitive radio [10] imparts superior performance in the LTE networks through providing awareness about the environment, in addition to making the decision on the tuning of transmission parameters in real-time [11]. The implementation of the Cognitive Radio Resource Management (CRRM) is achievable at any of the two levels, namely, the network level or the terminal level. The LTE networks make use of it to allocate the RBs or power and to adapt the modulation with the intention of enhancing the throughput as well as to cut down the effect of interference. But, the attainment of these objectives relies on the network operators, the place where the user is located, the network rules and the requirements that the QoS insists [22].

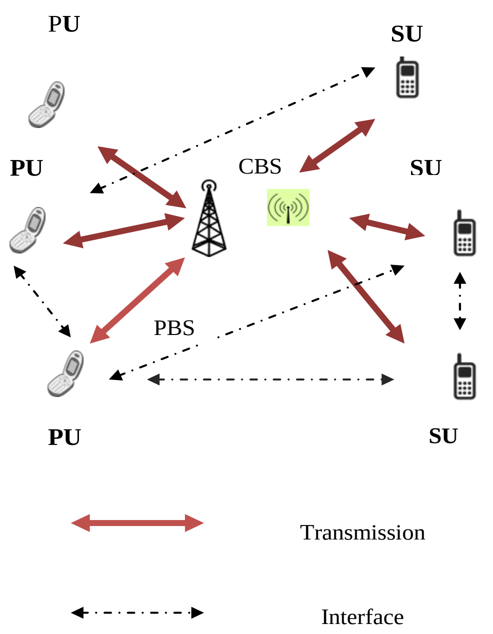

Fig.1 System model of OFDM based cognitive radio system

Evolutionary algorithms such as GA and PSO are used for optimization of the radio resource allocation [12] problem. They are used to manage the reduction of energy consumption and CO_2 emissions, along with the maximization of the network operator's profit [1]. The problem of allocating the resources also entails optimizing the duration of time, which is allotted to all network devices for bringing about an enhancement in the Quality of Service [2] and metrics such as outage, throughput and MOS are used for evaluating the performance of the optimization schemes [3].

This paper focus on proposing an improved version of the recently introduced optimization algorithm called as GSO tosolve the resource allocation problem more effectively. Possible improvements are produced through the introduction of dynamics on the GSO's maximum pursuit angle.

II. RESOURCE ALLOCATION MODELS

In 2014, Ghazzai et al [1] developed a formulation for the optimization problem to increase the gain pertaining to the Long-Term Evolution cellular operators and reducing the green house gas (CO_2) emission. They have proposed the methods, which work on the basis of Genetic algorithm as well as the Particle Swarm optimization, to cut down the energy utilization in base stations to a lowest level by optimizing the sufficient energy that are procured from the retailers.

They exploited the base station sleeping strategy model to optimize the problems and evaluated the performance and computational complexity of the developed methods. Hayward and Palacios [2] put forward a novel solution to resource allocation by developing a channel time allocation PSO method. The developed method solves the problem of network utility maximization resource allocation and improved the convergence speed with quality of service maintenance, thereby providing a solution to the real-time wireless networks. Liu et al [4] have introduced resource blocks, which are blank for the most part, for controlling the interference associated with the HetNet.

They have derived the structural nature that correspond to the optimal ABRB by using the sparsity, which comes into effect on the interference graph relative to the HetNet topology, and have proposed a two timescale optimization solution substitutes for having control over the ABRB.

In 2015, Monteiro et al [3] developed a power allocation framework in wireless network for maximizing the minimum MOS of the users and focussed on QoE-aware resource assignment.

They evaluated the developed framework by means of simulations. They considered a satisfaction factor which is needed for the heavily loaded systems. Li et al [5] have introduced an innovative uplink energy-efficiency (uEE) metric, which can be used with the wireless cellular networks.

They have analysed and found a solution to the joint optimization of the positions that the relay stations hold and the serving levels of the relay stations, in order to achieve an extremely large efficiency in terms of energy.

TABLE I. LIST OF PARAMETERS USED IN RESOURCE ALLOCATION MODELS

Parameters	**Ghazzai*et al***	**Hayward and**	**Monteiro *et al***	**Li *et al* [5]**

	[1]	Palacios [2]	[3]	
Profit (MU)	✓			
Operator attitude (ω)	✓			
Co_2 emission (Kg/hour)	✓			
Procured energies (%)	✓			
No of active BSs	✓			
No of users	✓			
User in outage (%)	✓			
Outage rate (%)	✓			
Active BSs	✓			
Number of Iterations		✓		
Swarm Diversity		✓		
Sum utility		✓		
GOP size (Bytes)		✓		
GOP number		✓		
CTA (ms)		✓		
Minimum MOS			✓	
Number of UES			✓	
Outage (%)			✓	
System throughput (Mb/s)			✓	
Uplink Energy Efficiency,UEE (kbps/W)				
Optimal values				
UC (kb/s)				
Cell radius (m)				
No of Relays (N_r)				
No of users ($\|U_T\|$)				
Capacity of users (kb/s)				

III. DISCUSSION

According to the review of radio resource management efforts reported in the literature, the primary contributions reside on optimizing the resource utilization and allocation principles. Hence, the review outcomes are summarized in Table I in the perspective of optimization problem. In other words, the radio resource management problem can be simply mapped to an optimization problem, as per the review findings. Though the superiority of each research effort has been sufficiently demonstrated, there are enough research gaps to be addressed. This even supports future researches that may result in the further improvement of the current practice. To provide a concise view of it, Table I comes with both merits and demerits of the adopted methodology in the radio resource management.

In [1], a combination involving the genetic algorithm as well as the particle swarm optimization methodologies have been adopted to minimize the usage of energy in the base stations based on the optimal power allocation principles. Despite the particle swarm optimization and genetic algorithm is known for its ability to understand a system, which could not even produce sufficient information about its characteristics. However, they are also known for its general drawbacks that remain unsolved. For instance, the particle swarm optimization has the problem of sticking with local optima and the genetic algorithm has often slow convergence rate. Both the algorithms highly rely on their parameters, which are usually generous. As a result, the sensitive management of radio resources often results in poor utilization and success rates. The similar kind of problems can be faced in [2], because of the usage of traditional particle swarm optimization.

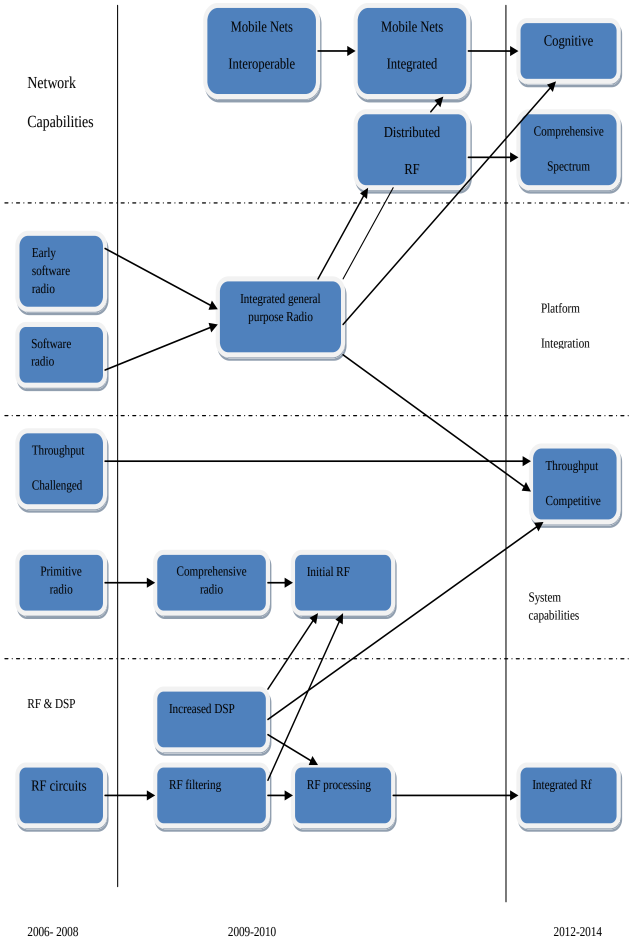

Fig. 2 Development of cognitive radio Map

TABLE II. REVIEW ON CONVENTIONAL RESOURCE MANAGEMENT PRINCIPLES FOR COGNITIVE RADIO SYSTEM

Author [Citation]	**Adopted Methodology**	**Advantages**	**Disadvantages**
Ghazzaiet *al* [1]	Genetic algorithm	Ability to determine an	Failure of convergence to the

	and Particle Swarm optimization	unknown system performance with least knowledge	global optima due to poor parameter settings, indefinite search space and imprecise objective model
Hayward and Palacios [2]	PSO	Simple and Fast Converging behaviour	Sticking with local optimal under multimodal scenarios
Monteiro *et al* [3]	Iterative framework of resource assignment and power allocation	Subjected to improve QOE along with QoS constraints	Bi-level characteristics of the framework introduces computational complexity
Liu *et al* [4]	Hierarchical procedure	Dynamicity over the network users	Suitable for less degree of network configuration
Li *et al* [5]	Joint optimization	Developed to analyze the uplink energy efficiency	Not generalized for optimal resource management
Zhi Tian *et al* [34]	Compressed sensing for dynamic resource allocation	Requires few number of iterations and minimal sampling rate to handle signal sparsity	Imprecise estimates on samples at the early iterations
Stefania Sardellitti, and Sergio Barbarossa [35]	Cooperative spectrum sensing	Improved precision in signal detection	Expensive, requires effective control scheme and information sharing algorithms
RenchaoXie*et al* [36]	Lagrangian method	Ability to handle constrained mixed integer problem model of channel allocation	Selecting the degree of approximation is complex
Mikohasegawa*et al* [37]	Hopfield - tank neural network	Memory to emphasize good learning ability	Suffers from regularization
Bo Chen *et al* [38]	Singular value decomposition	Less arbitrarization	Not flexible and computationally complex for nonlinear problems
ShankhanaadMallick*et al* [39]	Hungarian algorithm	Simple and efficient	Require more and correct information about the problem model
YahiaTachwali*et al* [40]	Greedy selection	Straightforward selection and produces substantial allocation	Inability to handle multimodal search space

In [3], an iterative process has been initiated for efficient radio resource management and so as to meet the QoE along with QoS requirements. While the iterative process is novel attempt, it follows the principle of considering the radio resource management problem into two, resource assignment problem and power allocation problem. This often results in solving bi-level optimization problem. It is well known that a bi-level optimization problem is mutually dependent on each other and hence it is computationally difficult to handle. Under such circumstances, the performance under a real scenario remains as an open ended challenge. In [4], a hierarchical procedure is introduced to enable coordination between inter-cell users to mitigate the interference. Such perspective of managing the resources in the cognitive radio is reported as dynamic in case of the radio resources. However, higher degree of network configuration, for instance more number of users and complex network topology, has not been exploited for substantiating the efficacy of the procedure.

In contrast to the aforesaid methodologies, a uplink energy efficient metric has been reported in [5] to simplify the process of cognitive radio resource management issue. For the purpose of rendering solutions to the problem, a joint optimization process has been exploited. Though the metric considers multiple network parameters to examine the network’s performance on resource utilization and success rate, the metric is limited to definite optimization constraint. Since the exploited joint optimization is not standardized yet, it is uncertain to work with other meta-heuristic methodologies.

IV. RESEARCH GAPS

The spectrum sharing and sensing share some of functionalities, most of the issues are similar to those of spectrum sensing, which is explained as follows:

A. Distributed power allocation

The cognitive radio ad hoc networks (CRAHN) user determines the transmission power in a distributed manner without support of the central entity, which may cause interference due to the limitation of sensing area even if it does not detect any transmission in its observation range. Thus, spectrum sharing necessitates sophisticated power control methods for adapting to the time-varying radio environment so as to maximize capacity with the protection of the transmissions of Primary users (PUs).

B. Topology discovery

The use of non-uniform channels by different CR users makes topology discovery difficult. Here, CR users A and B experience different PU activity in their respective coverage areas and thus may only be allowed to transmit on mutually exclusive channels.

C. Spectrum access and coordination

In classical ad hoc networks, the request to send (RTS) and clear to send (CTS) mechanism is used to signal control of the channel and reduce simultaneous transmissions to an extent. In CR networks, however, the available spectrum is dynamic and users may switch the channel after a given communicating pair of nodes have exchanged the channel access signal. Thus, a fresh set of RTS-CTS exchange may need to be undertaken in the new channel to enforce a silence zone among the neighbouring CR users in the new spectrum. Moreover, the CR users monitoring the earlier channel are oblivious to the spectrum change on the link. They continue to maintain their timers and wait for the duration needed to complete the entire data transfer before initiating their own transmission. This leads to inefficient spectrum use, and new coordination mechanisms among the CR users is necessary whenever the spectrum access conditions change. CR user C observes that the spectrum is currently being used by the CR users A and B. During the ongoing transfer,CR user A may detect a PU arrival, causing the spectrum on the link A-B to be changed. As this spectrum change occurs after the RTS-CTS control message exchange, user C continues to remain silent for the duration of the transfer specified earlier. This leads to lost spectrum opportunity as the PU detected by user A does not affect transmission by CR user C.

D. Evolution and learning

The occupancy history of the spectrum bands by the PUs may vary with the time of the day and location. It is desired that the MAC protocol learns the characteristic PU activity and accordingly alters its spectrum selection and data transmission strategy. Although the POMDP MAC protocol proposed, initial steps in this direction, more detailed and elaborate learning models are needed. How long should the learning duration be, and its effect during the network operation are issues that need to be investigated. Moreover, the problem of constructing detailed channel occupancy needs further research, so that the different times of the day and different locations traversed by the mobile CR user can be incorporated. The probabilistic spectrum selection algorithm that uses this history may be designed to guarantee performance bounds during long-term operation. For this, open challenges include how the theoretical research and network operation are combined, so that the gains arising from the choice of the spectrum at the link layer are appropriately weighted in each decision round, and the computational time for considering the past history is minimized.

V. CONCLUSION

In this paper, allocation of resources in the OFDM-dependent cognitive radio system has been discussed. Here, development of Cognitive Radio Resource Management (RRM) is phenomenal in sensor networks. Moreover, the main objective of RRM is to share the available and limited radio spectrum between users efficiently with secured Quality of Service (QoS) and high speed data transmission. Additionally, the problem of resource allocation in literature is summarized in Table I. Finally, Evolutionary algorithms such as GA and PSO are used for optimization of the radio resource allocation problem.

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