# A SURVEY ON DIFFERENT TECHNIQUES OF SPECTRUM ALLOCATION IN CONGNITIVE RADIO NETWORKS

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## ABSTRACT

*A cognitive radio (CR) is very significant technology to use a spectrum dynamically in wireless communication networks. This paper discusses about the spectrum management issue different techniques in Cognitive radio networks (CRNs). it is essential to use unused licensed spectrum band, also called the white spaces, for the better utilization of the spectrum. The availability of spectrum allocation of idle bands is a key approach to enhancing the utilization of wireless spectrum in cognitive wireless systems. Here, this paper review the different techniques used for the spectrum allocation in CRNs:*

1) *Priority Based Spectrum Allocation ;*
2) *Dynamic spectrum management;*
3) *Spectrum management using Swarm Intelligence.*

**Keywords:** *Quality Of Service(Qos), Cognitive Radio, Crns Cognitive Radio Network,CR Cognitive Readio, Primary Users, Secondry Users, Particle Swarm Intellignece, Spectrum Allocation, Look Up Table.*

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# I INTRODUCTION

Spectrum management is a technique in which capturing the best available spectrum to meet user communication requirements while not creating undue interference to other (primary) users. Cognitive radios should decide on the best spectrum band to meet the Quality of service requirements over all available spectrum bands, therefore spectrum management functions are required for Cognitive radios.

Priority based spectrum allocation scheme is basically used to allocate the spectrum on the basis of the priority which is settle down on the basis of three parameters: BER(bit error rate),throughput, and sustainable delay.

According to a statistical analysis survey, the spectrum utilization by the licensed users is as low as 15% [4]. So, this dynamic spectrum allocation technique motivates the cognitive radio technology which allows unlicensed users, known as secondary users (SUs), to utilize the licensed spectrum opportunistically. The cognitive radio senses the environment and allocates the idle bands, not used by the licensed users, to the SUs thereby increasing spectral efficiency. Opportunistic spectrum usage is discussed in the context of spectrum sharing. The idle bands, also referred to as *white spaces or holes*, is a set of frequencies which are assigned to the primary users (PUs) but are not utilized during a given time duration.

A swarm intelligence based algorithm, particle swarm optimization (PSO), is used to solve the spectrum allocation problem which is formulated into a multi-objective Optimization problem aiming at optimizing the system's overall performance.

# II. PRIORITY BASED SPECTRUM ALLOCATION

In this concept three novel priority-based spectrum allocation techniques for enabling dynamic spectrum access (DSA) networking for non-contiguous orthogonal frequency division multiplexing (NC-OFDM) transmission. Those schemes are: *First Available First Allocate* (FAFA), *Best Available Selective Allocate* (BASA) and *Best Available Multiple Allocate* (BAMA) based on the throughput and bandwidth utilization metrics. With each communication link in the network possessing a specified pair of bit error rate (BER) and throughput requirements for supporting a specific application, the proposed technique assigns one or more blocks of wireless spectrum to these applications in an attempt to simultaneously satisfy these requirements.

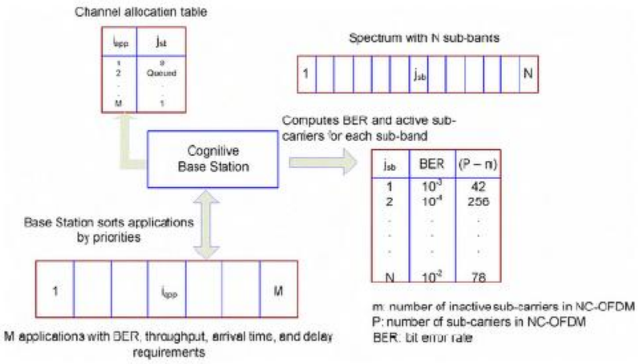
In ***First Available First Allocate (FAFA),*** the cognitive base station constructs a priority queue based on the arrival time of each application into the queue. FAFA selects the first application from the queue and allocates the first available sub-band that satisfies the BER requirement of the application. The scheme follows the same strategy for the subsequent sub bands.

In ***Best Available Selective Allocate (BASA),*** the cognitive base station constructs a priority queue based on the joint requirement of BER and delay requirements. So, in this, the cognitive base station allocates the best available sub-band that satisfies the selective requirement of a SU. This selective allocation is based on the prioritized BER and delay requirements and as well as the throughput, i.e., bandwidth demand.

In ***Best Available Multiple Allocate (BAMA)*** This multiple access technique has an initial operation similar to that of BASA described above. BAMA performs its spectrum allocation in two stages as follows:

• Allocation of prioritized requests to selective sub-bands similar to BASA; and

• Detects un-allocated user requests and allocates them to previously allocated sub-bands, which satisfies the BER and throughput requirements[11].




## III. SWARM INTELLIGNECE

In this, we use system's sum bandwidth benefit, second users' access fairness, and system's overall performance as the fitness functions respectively, and proposed a novel spectrum allocation algorithm based on PSO. The model of spectrum allocation can be expressed as an optimization problem, and we use the PSO algorithm, a swarm intelligence algorithm, to solve it.

The cognitive radio senses the environment and adapts itself to the changing environment through dynamic adjusting of the radio parameters, such as power, carrier modulation, and coding. Cognitive radio systems can intelligently use the white spaces and communicate reliably without interfering with the primary users whenever and wherever, thereby maximizing the spectrum utilization rate.

This paper discusses the allocation of the idle bands among secondary users after the system finish spectrum detecting. The spectrum allocation problem is the research hot spot in the field of cognitive radio. In recent years, researchers have studied about how to use the spectrum efficiently and flexibly. A graph theory based algorithm, Color-Sensitive Graph Coloring (CSGC), was proposed in [3], and the author abstracts the spectrum allocation problem into the graph coloring problem, but the algorithm's execution time increases with the increase of spectrum channels. In [6], the author proposed a parallel algorithm for spectrum allocation. The algorithm attains the same spectrum allocation benefit as CSGC algorithm while requiring less executing time, but it cannot ensure the secondary users' access fairness. So there are still many faulty aspects that need to be improved. In this paper, after analysing and discussing the graph coloring model of spectrum allocation, a novel spectrum allocation algorithm based on PSO, swarm intelligence based algorithm, is proposed which includes system's sum bandwidth.

### *A. PSO ALGORITHM*

The PSO algorithm stochastic initializes a population in D-dimension search space [5-7]. The individuals of the population are called particles and each individual represents a possible solution. The fitness function decides the solution's quality. Each particle flows through the *D* dimension search space and the movement is influenced by two factors: its own best solution and any particle's best factors, which are called cognitive component and social component respectively. As the particle traverses through the search space, because of the first factor, each particle stores its own best solution in memory and experiences a pull towards this position, called pbest; as a result of the second factor, the particle also stores any other particle's best factors in memory and experiences a pull towards this position, called gbest. In term of fitness, the value of pbest and gbest will be updated if a more dominate solution is found by the particle and by the population after each iteration. This process is continued iteratively until either the desired result is achieved or the computational power is exhausted. The standard PSO defines each particle in the D dimensional space as:

$$x_i^t = (x_{i1}^t, x_{i2}^t, \dots\dots x_{iD}^t)^T$$

The pbest and the gbest are recorded as:

$$p_i^t = (p_{i1}^t, p_{i2}^t, \dots\dots p_{iD}^t)^T$$

The velocity of particle i is represented as:

$$v_i^t = (v_{i1}, \dots, v_{id})^T$$

$v_{id}$ and $x_{id}$ are manipulated according to the following equations:

$$v_{id}^{t+1} = \chi(wv_{id}^t + c_1r_1)(p_{id}^t - x_{id}^t) + c_2r_2\left(p_{gd}^t - x_{id}^t\right)$$

$$x_{id}^{t+1} = x_{id}^t + v_{id}^{t+1}$$

Where $\chi$ is known as constriction coefficient; w is the inertia weight; $c_1$ and $c_2$ are the learning rates; and $r_1$, $r_2$ are two random vectors uniformly distributed in [0, 1].

The binary PSO is used in this paper. The velocity and the position update equations for the binary model are given as following:

$$if\left(rand\,() < S(v_{id})\right) then\ x_{id} = 1; else\ x_{id} = 0$$

$$S(v_{id}) = \frac{1}{1 + exp(-v_{id})}$$

## IV. DYNAMIC ALLOCATION

Cognitive Radio (CR) is relatively a new technology, which intelligently detects a particular segment of the radio spectrum currently in use and selects unused spectrum quickly without interfering the transmission of authorized users. Cognitive Radios can learn about current use of spectrum in their operating area, make intelligent decisions, and react to immediate changes in the use of spectrum by other authorized users. The goal of CR technology is to relieve radio spectrum overcrowding, which actually translates to a lack of access to full radio spectrum utilization. Due to this adaptive behaviour, the CR can easily avoid the interference of signals in a crowded radio frequency spectrum. The proposed scheme also mitigates the delay of the licensed primary users due to minimized switching.

### *A. OPPORTUNISTIC SPECTRUM ACCESS (OSA)*

Basic components of *Opportunistic Spectrum Access (*OSA) include spectrum opportunity identification, spectrum opportunity exploitation, and regulatory policy. The opportunity identification module is responsible for accurately identifying and intelligently tracking idle frequency bands that are dynamic in both time and space. The opportunity exploitation module takes input from the opportunity identification module and decides whether and how a transmission should take place. The regulatory policy defines the basic etiquette for secondary users to ensure compatibility with legacy systems. The overall design objective of OSA is to provide sufficient benefit to secondary users while protecting spectrum licensees from interference. The tension between the secondary users' desire for performance and the primary users' need for protection dictates the interaction across opportunity identification, opportunity exploitation, and regulatory policy. The optimal design of OSA thus calls for a cross-layer approach that integrates signal processing and networking with regulatory policy making [7].

### *B. Diagram of proposed model*

In this the proposed algorithm to allocate a channel to SU based on prior experience as a spatial function of time. In this approach, the cognitive radio technology uses the real time knowledge of its environment to adapt its behaviour dynamically with the intent to enhance its operational efficiency.

Algorithm's Primary objective is to:

- Minimize switching of SU to reduce the average switching delay.
- Keep a database of past usages of channels by PU as a function of time duration.

A time band counter which is maintained in two dimensional array based on the past utilization of the channel by PU.

24hrs

| | $t_1$ | $t_2$ | … | $t_n$ |
|---|---|---|---|---|
| Channel 1 | C[1,1] | C[1,2] | … | C[1,n] |
| Channel 2 | C[2,1] | C[2,2] | … | C[2,n] |
| … | … | … | … | … |
| Channel m | C[m,1] | C[m,2] | … | C[m,n] |

**Figure 1. The usage matrix maintaining the usage history of channels**

Here, *c[i,j]* maintains the count how many times the *ith* channel has been utilized in *jth* time band as an average by PU. A sorted list in ascending order is maintained according to value of *c[i,j]*.

This approach guides us to allocate a channel to SU based on past utilization of a channel by PU. We try to allocate a channel to SU with minimum usage by PU so far keeping in view that the recent past is the best approximation of near future. This data structure is maintained at each base station. The highest priority is always given to the request of PU. When a match is found [8], the transmitter first detects the receiving activities of primary users in its neighbourhood (see Figure 2). If the channel is available (no primary receivers nearby), it transmits a short request-to-send (RTS) message to the receiver. The receiver, upon successfully receiving the RTS, knows that the channel is also available at the receiver side and replies with a clear-to-send (CTS) message. A

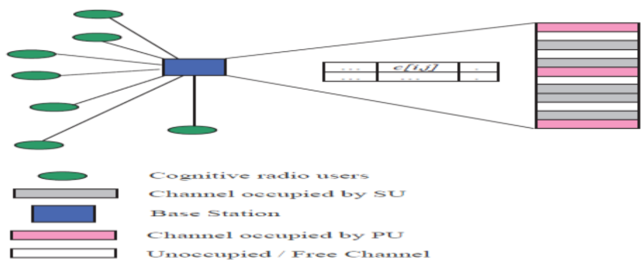



**Figure 2: Block diagram of proposed algorithm**

Successful exchange of RTS-CTS completes opportunity detection and is followed by data transmission.

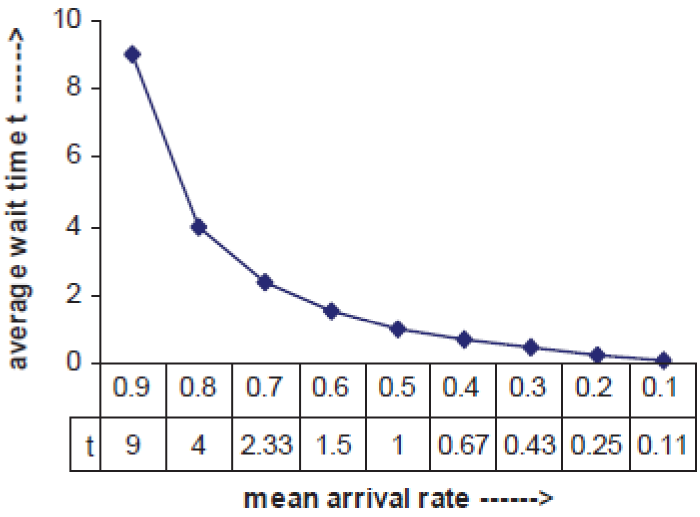
Queuing analysis is used in this dynamic allocation technique discussed as follows:

Base station is used to keep record of all the unused channels and so it is known as the server station, base station queue all the request from SU's. There is a random arrival of every new request from the SU's and its burst time is also random. Hence it can be modelled as M/M/1: FCFS Queuing system (assuming sufficient no. of channels to serve SU and PU requests).

Average waiting time, $t$ is can be taken as:

$$t = \frac{\lambda}{\mu * (\mu - \lambda)}$$

where $\lambda$ is the mean arrival time and $\mu$ is the service time. If each channel is considered as a sub-server, and allocate the SU requests according the usage matrix [figure 1], the mean arrival rate $\lambda$ is reduced for a particular channel. It will reduce the average waiting time of the SU requests. Keeping the $\mu$ the mean service time is constant; the graph shown in Figure 3 depicts the behavior of average waiting time as a function of arrival rate $\lambda$:




## V. COMPARISON

In The dynamic allocation proposed work unique as no other approach takes into consideration the priorities for both the SUs as well as the channels in the operating spectrum along with the past usage data.

Whereas the model of spectrum allocation can be expressed as an optimization problem, and we use the PSO algorithm, a swarm intelligence algorithm, to solve it. The PSO algorithm's performance is enhanced than dynamic proposed algorithm.

Priority based scheme in spectrum allocation is much more relevant as it is giving three scheduling schemes to allocate spectrum. so it is surveyed is that after swarm intelligence method the priority based method is more relevant and effective also.

## VI. CONCLUSION

In dynamic allocation scheme the channel characteristic to mitigate the delay. As a future work we are planning to incorporate the factor of time span a channel is used by a PU. It may be associated with the permitted delay of the request by SU as a waiting time.

Hence in dynamic allocation scheme, to serve the requests in FCFS order may cause some smaller requests to wait for longer requests to finish. It will increase the average waiting time. SJF algorithm will be better to reduce the average waiting time.

The proposed algorithm using swarm intelligence is especially adaptive to the cognitive radio spectrum allocation in the slow changing environment. The PSOOP algorithm's enhanced performance tradeoffs between PSOMSB algorithm and PSOMAF algorithm, and this indicates that the enhancement of secondary users access fairness performance is cost by sacrificing the sum bandwidth reward.

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## REFEENCES

1. Haykin S. Cognitive Radio: Brain-Empowered Wireless Communications [J]. IEEE Journal on Selected Areas in Communications, 2005, 23(02):201-220.
2. Motola J, Maguire G Q. Cognitive Radio: Making Software Radios More Personal [J]. IEEE Personal Communications, 1990, 6(4): 13-18.
3. Peng C, Zheng H, Zhao B Y. Utilization and Fairness in Spectrum Assignment for Opportunistic Spectrum Access [J]. Mobile Networks and Application, 2006, 11: 555-576.
4. Mehmet S, Ramazan K. A comparative study of multiobjective optimization methods in structural design [J].Turk J Engin Environ Sci, 2001,25 :69-78.
5. Liao Chu-lin, Chen Jie,Tang You-xi, et al. Parallel Algorithm of Spectrum Allocation in Cognitive Radio [J]. Journal of Electronics & Information Technology, 2007, 29(7):1068-1611.

6. Eberhart R C, Kennedy J. A New Optimizer Using Particle Swarm Theory [C]. Proceedings of the 6th International Symposium on Micromachine and Human Science, Nagoya, Japan, 1995, 39-43.
7. Q. Zhao, L. Tong, A. Swami, and Y. Chen, "Decentralized cognitive MAC for opportunistic spectrum access in ad hoc networks: A POMDP
8. framework," IEEE J. Selected Areas in Commun.: Special Issue on Adaptive, Spectrum Agile and Cognitive Wireless Networks, vol. 25, no. 3, Apr. 2007.
9. Qing Zhao and Brian M. Sadler, A Survey of Dynamic Spectrum
10. Access: Signal processing, networking, and regulatory policy; IEEE SIGNAL PROCESSING MAGAZINE MAY 2007.
11. Beiwei Zhang, "Spectrum Allocation In cognitive Radio Netwroks Using swam intelligence", second international conference on commmunication and netwroks,2010.
12. Sharma parbhakar, Tapaswi Shashikala, "Dynamic Spectrum Allocation Technique in Cognitive Radio Networks", IEEE 2011.
13. Chittabrata Ghosh, Si Chen, Dharma P. Agrawal and Alexander M. Wyglinski, "Priority-based Spectrum Allocation for Cognitive Radio Networks Employing NC-OFDM Transmission" IEEE 2009.