Dynamic Spectrum Allocation Using Improved Particle Swarm Optimization and Graph Coloring Problem incorporating outputs of Learning Schemes

Dr. Anju Kulkarni¹, Dr. Mithra Venkatesan², Ms. Snehal Ratnaparkhi³, Dr. Radhika Menon⁴

¹ Professor, D.Y. Patil Institute of Engg. & Technology, Pimpri, Pune-18
² Associate Professor, D.Y. Patil Institute of Engg. & Technology, Pimpri, Pune-18
³ PG Student, D.Y. Patil Institute of Engg. & Technology, Pimpri, Pune-18
⁴ Professor, D.Y. Patil Institute of Engg. & Technology, Pimpri, Pune-18

Abstract: Rapid growth in the technology of wireless devices and application has increased the need for wireless spectrum. The traditional static spectrum is unable to fulfill this tremendous spectrum needs and hence results in bottleneck condition. Cognitive Radio provides a powerful solution to this spectrum shortage and provides spectrum utility by the quality of Dynamic Spectrum Allocation. In cognitive network conditions like communication, deterioration happens due to poor matching between user demands and spectrum resources and inefficient spectrum utilization which is the result of unnecessary matching. Customer service oriented model based on Graph theory and Particle Swarm Optimization (PSO) is developed in this paper, in order to discover a better solution for spectrum allocation. The problem is described using Graph Coloring Problem and PSO ease the spectrum allocation optimization, so as to maximize the cognitive network spectrum utilization. The proposed method includes the contribution of learning accomplished through predictive models, in spectrum allocation. Being a services oriented approach, the proposed method achieves maximum network reward, throughput, fairness and good iteration efficiency.

Keywords: Cognitive radio, Dynamic Spectrum Allocation, Learning, Graph Coloring Problem, Particle Swarm Optimization, Network reward
1. Introduction

The need for wireless spectrum has tremendously increased with rapid development in communication resources and services. The mismatch between users demand and available spectrum in traditional static spectrum allocation strategies result in scarcity and condition of bottleneck has arrived [1]. Cognitive Radio is a promising technology aiming to fulfill this communication network flaw [2]. Using Cognitive Radio features, spectrum can be utilized very efficiently and wastage of spectrum can be avoided.

Cognitive Radio is an Artificial Intelligent radio having cognitive capabilities and reconfiguration i.e. its skill to sense and collect information from its adjoining environment. Cognitive Radio senses the best available spectrum for communication or spectrum hole and uses that spectrum for communication. Dynamic Spectrum Allocation [3] is the advance feature of Cognitive Radio used to improve spectrum utilization. It improves by dynamically assigning the spectrum after sensing the spectrum holes from the cognitive users without any interference to other licensed and unlicensed users. As a part of intelligent communication technology, it plays an important role for sharing of the spectrum resources between primary and cognitive users [4]. Availability of spectrum is based on historical information predicted by present approaches such as Markov chain [5,6] and Reinforcement learning models [7] without interference with primary users. Problem-related to fairness, interference and network rewards are eliminated using other approaches like Graph coloring problem (GCP) [8], Auction theory [9, 10], Game theory [11]. These models enhance the allocation efficiency by coordinating opposition between cognitive users.

Tragos et al. [2] present a brief overview of the problem of spectrum assignment. Authors have analyzed criteria for selection of spectrum bands, their different approaches and several techniques for allocation. It has been established that GCP algorithm is very easy to implement and adapts well in the practical environment. Further, traditional GCP reduces the collision probability between primary and secondary users. Also, when primary and secondary users are close to each other using GCP enables lower channel utilization. Its ease of implementation and adaptation to the real environment are reasons for this development. Wang et al. [12] used GCP to solve problem-related spectrum utilization, fairness and throughput problem in CR networks. Time and frequency division multiplexing is used for practical strategies of channel allocation. This paper provides solution to the problem of channel sensing, channel allocation, channel accesses and channel switching.

Allocation problem is converted into an NP problem based on GCP presented by [13] Peng et al. [14] work is to increase allocation efficiency. Three traditional allocation
rules are applied where the author transforms spectrum allocation into NP-hard problem. Canberk et al. [15] have proposed GCP based on QoS grading method. Diversity between users is also included. But this algorithm fails to explain matching problem between users’ service type and spectrum characteristics. Zhang et al. [16] propose the methodology which considers bandwidth matching between secondary users’ bandwidth requirement and available channel. It improves total spectrum utilization to provide protection to primary users. Many of these algorithms have time overhead. To improve this problem, Wei et al. [17] present parallel allocation. An improved version of this algorithm is presented by Wang et al. [18], where the allocated node is able to obtain all available channels at one time, but results in lower fairness. A flexible method is proposed to balance network reward and fairness performance. It is an advanced power adaptive spectrum allocation algorithm which collaborates a degree of interference, time overhead and increases switching cost. Huixin et al in [19] introduces the technique which collaborates GCP and parallel immune optimization. Using this method computational time reduces. With the higher network, profits efficiency also increases. This paper is based on qualitative analysis. Ge Yuming et al. [20] introduce complex two-level network architecture. This algorithm takes into consideration service demands by ranking spectrum selection. Matching optimization is done at the network level. This algorithm improves overall network performance but brings in some delay factors.

Currently, for efficient solution of non determinstic polynomial (NP) problem and allocation, bio-inspired algorithms are used [21]. It is less complex, having more computational feature and easy to implement, thus receiving significant attention. Genetic algorithm [22], Particle swarm optimization [23], Ant colony system [24] are some commonly used bio-inspired algorithms.

Presently bio-inspired algorithms are used to solve NP problem. Pyari Mohan Pradhan et al. [25] have performed a comparative analysis of evolutionary algorithms. This study is performed on both single and multi-carrier communication system. The performance of different algorithms is compared based on convergence characteristics and four statistics matrices. Enhanced binary particle swarm optimization algorithm proposed by Ab Delsalam et al.[26] considers the utilization in cognitive networks and computational time. When compared to DSA-GA and DSA- ACO, PSO provides good iteration efficiency, fewer parameters to adjust and more stable performance.

For improved efficiency of allocation some systems also uses hybrid methods [27]. Liu et al. [28] proposed the method based on GCP and PSO for allocation of spectrum with fairness and better utilization achieves. This algorithm is service oriented that consider user demands and spectrum characteristics. GCP is used as
channel allocation NP-hard problem. PSO is used for allocation with comprehensive, multi-objective decision mechanism for more efficient utilization of the spectrum and better network reward. This algorithm also converges rapidly and provides good iteration efficiency.

Tang et al. [29] proposed a solution to achieve significant throughput and efficiently solve the non-convex optimization problem. Under the strict assumption, non-convex problem transform into the convex problem. The proposed algorithm in this paper uses PSO and stimulated annealing (SA). Koroupi et al. [30] collaborates ACO with GCP for spectrum allocation and the result obtained from it is compared with classic PSO and generalized special congestion games (GSCG). This algorithm is based on GCP and Ant Colony System (ACS). Mainly author compares the performance of proposed algorithm with Color sensitive graph coloring (CSGP) and PSO. The authors have concluded that the result of ACO is better than above two methods but the processing time is greater. In [25], different algorithms performance has been compared based on convergence characteristic and statistical metrics.

The proposed method is an extension of work [33]. In [33] authors have done allocation for higher reward value. In proposed method priority of users are considered based on their prize value. It also considers the frequency utilization by allocating same channel to more than one user. In proposed method we consider priority of users and channel along with network sub reward matrices.

The Graph Coloring Problem (GCP) is very efficient and its implementation is adequately simple. The collision probability between cognitive users and primary users can be reduced by using this algorithm. Considering these advantages GCP is used to describe NP problem for the proposed system. PSO is the other half of proposed system for allocation. Considering the advantages of Particle Swarm Optimization like convergence time, efficiency, less parameter to adjust, fewer complexes over other algorithms, proposed method uses PSO for efficient spectrum allocation [28][30].

In [34] author have introduced multi service based MBSO algorithm with algorithm allocation done for higher reward value. In this approach, same channel is not allocated for multiple users. Liu [28] has extended this work by using optimization algorithm of PSO. All parameter in both algorithms are generated statistically. In the proposed method dynamic generation of the network and value is done. The system has problem of stability. The learning approach and priority of users provide novelty to the work. Very few aforementioned researches are based on multiservice-oriented approach. They are either based on reward function values or consider multiple
attributes characteristics to obtain a more comprehensive reward with respective users’ demands.

Further, Katidiotis [31][32] et al proposes predictive learning algorithms towards prediction of data rate and throughputs. These predicted values of throughput can act as valuable inputs for spectrum allocations.

Hence the proposed work is aimed towards building a Dynamic Spectrum Allocation model using GCP and PSO for customer multi-service type network with network parameter generated randomly. The novelty of the proposed work is in the incorporation of inputs from the predictive model which plays a vital role in Dynamic Spectrum Allocation. The proposed method considers priority of users based on prize compensation so that high priority users are allocated first followed by other. The proposed algorithm allocates channel based on demand which makes the proposed work novel. While other multi-service oriented algorithms cannot assign channel on demand and for more than one user, the proposed method can allocate same channel based on final outcomes obtained from GCP and PSO.

The network is generated and parameters are initialized using GCP, following which in accordance to service type a complete prize matrix is formulated including weight age for throughput from the predictive models. Following this, the priority of secondary users is set and allocation of available spectrum is accomplished using Particle Swarm Optimization.

2. Methodology

The proposed methodology integrates GCP and PSO algorithms to efficiently satisfy service demands with better utilization and fairness. The allocation dilemma is mapped to a Non-Polynomial (NP) hard graph coloring problem and PSO has very low complexity to solve this problem. This multi-objective decision model uses centralized network architecture. The spectrum allocation process is divided into two parts namely the sensing and allocation process. The assumptions are that the sensing results are just proper and network environment does not vary through one allocation cycle. The proposed system is represented as block diagram shown in Fig.1.
2.1 Initialization of Network model

2.1.1 Network representation as a Conflict graph model

Combining GCP with channel allocation strategies improves channel utilization. The proposed work leads toward achieving channel utilization in simple and efficient way. Using GCP available channels and interference condition between users as a binary matrix is abstracted. The dynamic allocation of channel resources to cognitive users from the global point of view is done. Further, utilization of channels and
network performance is done by avoiding interference with licensed users. The dynamic allocation using GCP is not efficient so proposed method used bio inspired based channel allocation strategy to improve channel utilization.

Fig. 2 shows the system model for understanding of GCP. This is an example of one system model which consist of three primary users and six secondary users. A specific channel is assigned to particular primary users. The primary users are authorized users and secondary users are unauthorized users. Based on prize compensation proposed model having different types of secondary user’s gold, silver, copper and red each having specific priority. Gold users are shown in yellow color, silver by silver colour, copper user by orange colour and red users by red color. As represented in model SU1 is gold user, SU, SU6 are silver, SU 2 is copper and SU4 is red user. These priorities are generated randomly. To covert this system in to conflict graph model each primary users are represented with help of circle and secondary users in the form of vertex. Using GCP one can abstract various parameter of network which given as follows. In proposed model conflict graph of the network is formed randomly in X×Y region using MATLAB functions. Scenario of network has assumed. The network is formed with M primary users and N cognitive users having label ranging from 0 to M-1 for primary and 0 to N-1 for cognitive users. Using this graph one can assume primary and secondary users location and primary users range. These users are distributed randomly in the set area. It is hypothetical that the offered spectrum resources are separated into K mutually orthogonal spectra. The specific channel is assigned to primary users while cognitive users come up for channel assignment within the coverage area of the primary users. A primary user inhibits a channel K with a radius of protection area denoted by a circle. Graph coloring problem is formulated in terms of edges and vertexes. Each secondary user is represented in terms of vertexes. Interference between different cognitive users on each channel represents in the form of edges. Conflict graph for system model is shown in Fig. 3. Thus the channel allocation dilemma can be formulated as GCP [13][28]. GCP reduce the collision probability between primary and cognitive users. Channel utilization also lowers when cognitive users are not often able to effectively use licensed channel because primary and cognitive users are close to each other.
The multi graph or pseudo graph is formed using vertexes and edges. Each primary user is having its own coverage circle. Pseudo graph for above system model is shown in Fig. 3. As shown in graph circle denotes PUs. SUS represented by vertexes. Interference between users is represented by edge.

2.1.2 Evaluation of network parameter using GCP
The network parameters are obtained from conflict graph. Main aim for using these GCP parameters is to avoid interference between users so the network performance not affected. The various parameter matrices are described as follows:

**Channel availability matrix**-

If authorized user means primary user occupies the channel, then the unauthorized user with cognitive ability cannot use this channel within power coverage of primary users described as $X_{ij}=0$ when secondary user is in power convergence range of primary user, otherwise cognitive users can use the channel shown by $X_{ij}=1$. If unauthorized user near the primary user then to avoid interference that channel is also not available for secondary users. This matrix denoted by X and can be expressed as

$$X=\{ x_{ij} | x_{ij} \in \{0,1\} \}^{N \times K}$$  \hspace{1cm} (1)

Two dimensional matrix is formed having values 0 or 1 based on channel availability for specific secondary users. Here j is no. of channels and i is secondary users. Based on graph generated in MATLAB availability of channel for particular user is abstracted and it is shown by pink color with label in Fig. 3. As shown in Fig. 2 secondary user 1 is not in range of any other primary user so available channels for SU1 are 1, 2 and 3. So there is value 1 for matrix for these channels. SU 2 is in range of primary users 1 so probability of interference for channel 1 is high. SU2 create interference to PU 1 so SU2 cannot use channel 1 so value in X matrix for channel 1 is zero and for other channels is 1. Likewise values are calculated for rest of users.

**Interference matrix**-

Different users occupy a channel and hence it causes interference for a channel. Channel j is occupied by user i and user m then condition of interference arrives denoted by $Y_{im,j}=1$ otherwise zero for noninterference. The interference between cognitive users is represented by edges in the graph. The channel assigned to the secondary user is in such a way that interference to the primary user should be less and within the certain threshold. As the location of a primary user is known to the secondary user, so interference to the primary user can be calculated. The main criterion is to protect the transmission of a primary user from secondary user transmission [2]. Interference between different users have denoted by matrix Y and expressed as

$$Y=\{ y_{im,j} | y_{im,j} \in \{0,1\} \}^{N \times N \times K}$$  \hspace{1cm} (2)

As shown in Fig. 2 as SU1 can use all available channels. SU2 and SU3 are also uses channel 2 and channel 3. These users are near to each other and using same channel so the possibility of interference is high. Interference between these users represented with the help of edge. And value for this in three dimensional matrix for that specific
channel where both users create interference is 1. SU6 cannot interfere with any other SU hence in three dimensional matrix this value represented by 0.

Noninterference allocation matrix:

This noninterference matrix $A$ records the result for one allocation process. It records the result $z_{i,j}=1$ for spectrum $j$ is allocated to user $i$ otherwise zero. This matrix is nothing but individual gain achieve by selling particular channel. In proposed method after optimizing for channel allocation problem particular channel is assign to particular user that value is represented by 1 in matrix $Z$ and for rest by zero. For an example channel 3 is assign to SU3 then value in matrix is 1 for channel 3 and for 1 and 2 value will be zero.

$$Z=\{z_{i,j}|z_{i,j}\in\{0,1\}\}_{N\times K}$$

(3)

2.2 QoS approach:

After calculating various parameters from GCP the information such as available channels and interference we get. These channel allocation for particular user is consider as NP problem. To solve this problem by simple and efficient way we are using PSO optimization algorithm.

2.2.1 Initialization of service Type:

The service type of cognitive users is randomly selected. The information regarding service type is available to Cognitive Radios. This information generated randomly is considered as sensed information from the environment and according to that, it modifies the parameter of the channel based on service.

2.2.2 Multi-service oriented estimation of Reward matrices:

2.2.2.1 Initialization of Sub- Reward Matrices

There are $M$ channels available for any cognitive user. Each channel is described by $K$ quality feature. In proposed work bandwidth ($B$), Power efficiency ($P$), Spectrum availability ($A$), Throughput ($\Delta$) are four attribute characteristics which are used to reflect system reward. The diverse users require different service matrices. The preference is based on service types. The weights for service types are given by preferences. Using multiple attributes and these preference weight normalization descriptions of the users are developed which is used to calculate complete prize matrix. It reflects stipulate to compute a better overall network reward. The model focuses on common wireless communication service type’s i.e audio, video and data. This makes model serving customer type requirement. In model specific value of
frequencies are decided for audio, video and data users. The bandwidth of the
cognitive user above or equal to this value differentiates service as audio, video, and
data.

2.2.2.2 Bandwidth reward

This attribute defines the spectrum limits of a channel. This limit is defined in terms
of the lower and upper frequency of the signal passing through the channel. A lack of
bandwidth is the outcome in distortion of the signal. So this attribute is a key aspect
in the allocation of spectrum. The specific value within ISM frequency range is randomly generated. The reward matrix for bandwidth represented as follows:

$$B = \begin{bmatrix} b_{11} & \cdots & b_{1K} \\ \vdots & \ddots & \vdots \\ b_{N1} & \cdots & b_{NK} \end{bmatrix}_{N \times K}$$  \hspace{1cm} (4)

2.2.2.3 Spectrum availability probability reward:

At specific condition the idle time length and idle frequency of the channel are
different. Longer idle time results in lower probability of spectrum switching and outcome of this increase in network reward. In time quantum, utilization of the spectrum is denoted by value in range 0 and 1. The low availability probability is denoted by 0 and vice versa. This attribute represented by

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1K} \\ \vdots & \ddots & \vdots \\ a_{N1} & \cdots & a_{NK} \end{bmatrix}_{N \times K}$$  \hspace{1cm} (5)

2.2.2.4 Power consumption

This matrix is the reward of user’s power transmission. The transmission provides
the restriction in interference representation. The change in restriction results in interference matrix. This matrix is related to communication range. This objective is calculated using P which is transmission power of cognitive users and $P_{\text{max}}$ is maximum available transmission power.

$$\text{PW}=1-\frac{T_P}{P_{\text{max}}}$$  \hspace{1cm} (6)

This metrics is given by
2.2.2.5 Throughput matrix

The throughput function $\Delta$ is defined as a number of bits received or transmitted correctly per second with $R$ as transmission rate and packet loss as $L$.

$$\Delta_{i,j} = X f(\delta)_{i,j}$$

(8)

$X = \frac{ML}{R}$ b/s this is the transmission rate of M payload bits. Packet success rate is defined by $f(\delta)$. The probability is defined by the function of signal to interference noise ratio (SINR). The packet succession probability depends on Bit error rate (BER) and SINR. Higher the value of both results in higher packet succession probability. BER also define by notation $P_e$ hence value of $f(\delta)$ becomes $f(\delta) = (1 - P_e)_{i,j}$

(9)

Putting Eq (9) in Eq (8) we get throughput function

$$\Delta_{i,j} = X (1 - P_e)_{i,j}$$

(10)

For each service type throughput range is different defined in Table (1). Throughput matrix generates values within that range for each service type.

$$\Delta = \begin{bmatrix} \Delta_{11} & \cdots & \Delta_{1k} \\ \vdots & \ddots & \vdots \\ \Delta_{N1} & \cdots & \Delta_{NK} \end{bmatrix}_{N \times K}$$

(11)

Values of these throughputs have predicted from learning algorithm. Based on these values proposed method predict its service type and apply weighting factor for specific service. Machine learning technique progressively improves the service preferences to match user preference.

2.2.2.6 Estimation of Complete prize matrices

Each service types have different needs of attributes. High bandwidth and spectrum availability is a requirement of video users so that they can achieve real-time video conferencing or video streaming. Audio users prefer larger bandwidth. For data users, low packet loss and fewer error rates are preferred. In mobile communication system bandwidth is very scarce resource. For audio user bandwidth is very important factor. With low bandwidth condition of deterioration occurs, which results in poor quality of video and audio. To offer the proper service wide range of bandwidth is required. Some users may consider high bandwidth. By giving
high preference to this bandwidth factor one can reduce the loss. As increase in the mobile users more channels are required to offer the service. So to satisfy user’s demands weighting sum approaches are used. Different preference weights are given to these service types. In the formulation of complete prize weight vectors for audio, video, and data are $W_1$, $W_2$ and $W_3$ respectively.

$$W_1 = \{w_{11}, w_{12}, w_{13}, w_{14}\}$$

$$W_2 = \{w_{21}, w_{22}, w_{23}, w_{24}\}$$

$$W_3 = \{w_{31}, w_{32}, w_{33}, w_{34}\}$$

Specific weight for sub rewards is used. This is one of technique to solve optimization problem. It involves multiple objective functions. Complete Prize is the combination of four attributes of the channel that is $B$, $P$, $A$ and $\Delta$ and its specific weight depends on the service type. Complete Prize reward is given as

For audio user

$$C_{ij} = w_{11} \cdot B_{ij} + w_{12} \cdot T_{P,ij} + w_{13} \cdot A_{ij} + w_{14} \cdot \Delta_{ij}$$  \hspace{1cm} (13)$$

For Video users

$$C_{ij} = w_{21} \cdot B_{ij} + w_{22} \cdot T_{P,ij} + w_{23} \cdot A_{ij} + w_{24} \cdot \Delta_{ij}$$  \hspace{1cm} (14)$$

For Data user

$$C_{ij} = w_{31} \cdot B_{ij} + w_{32} \cdot T_{P,ij} + w_{33} \cdot A_{ij} + w_{34} \cdot \Delta_{ij}$$  \hspace{1cm} (15)$$

It is nothing but benefit matrix user $i$ gains from using spectrum $j$ by checking availability matrix. This is weighting sum approach where each objective is provided a weight based on their objective preference. The reward can be a capacity of using the channel $j$ or maximum bandwidth/throughput that can be acquired assuming the interference constraints. The multiple objectives are weighted in parallel to generates single objective function so yield is simple and easy to implement. The weight of each objective function represents its importance in the current functioning scenario. The advantage of this weighting factor is that system can toggle dynamically to any object by only simply changing the weight assigned to each objective.
Data, video and audio users differ from users using specific range in ISM frequency. The user below or equal to these values is considering as that user type. The preference values are given to that range.

2.2.3 Estimation of priority matrix:

Each cognitive user has its priority to allocate the channel. When allocated, the spectrum is not fully utilized by primary users as they make a profit by selling that spectrum to cognitive users opportunistically. There is prize compensation between multiple secondary users. The proposed method considers Gold users are top paid users. At second levels there are silver users followed by copper users. At bottom level, there are red users. Gold users have the higher priority of allocation followed by others. After considering paid users, level users who need spectrum are allocated based on their priority. At one time, both requests from cognitive users and primary users are served. A cognitive user having high priority is allocated first to the available spectrum for that user.

2.3 Optimization using PSO

For allocation process, PSO [23][26] algorithm is used. The bio-inspired algorithm has high efficiency to solve NP problem and PSO is superior among all. The PSO algorithm is inspired from flocking of birds or schooling of fish. The PSO learns from these two scenarios to solve the optimization problem. The best strategy of PSO is to find best or nearest solution to optimization. The concept of PSO has based on swarm intelligent means collective behaviors of primitive agents that are interacting locally with its environment, create consistent global function pattern. PSO uses a population of particles or the individual objective functions in the population are consider as particles. These are mass less, volume less and focus to velocities and accelerations towards a better performance. Swarm is nothing but the irregular movement of particles in problem space. Particles are swarming in hyperspace with given velocities. According to the historical best position for the particle and neighboring best position velocities of the individual, particles are stochastically adjusted at each iteration. The particle best and neighboring best values are derived according to a user defined fitness function. One can say that PSO is an extension and a potentially important manifestation of “Cellular automata (CA)”. Swarm can be conceptualizing as a cell, whose state change in many dimensions. Some common attribute they share are

i. Individual particles or cell parallel updated

ii. Each new value depends on historical value of particle or cell and its neighbors
iii. All updates perform by the same tool.

At the time of each iteration, an updated value of velocity is considered as the memory for particles so that optimal solutions information is reserved for all individuals.

The proposed system is using modified PSO for allocation. The solution space of PSO is considered as priority matrix. For high priority matrix, we consider user channel comprehensive value. The local cost values are generated by optimizing this comprehensive array using PSO. For global cost value or value having high comprehensive value available channel is allocated to the user. The process is repeated for next priority users. PSO is run till maximum iterations reached.

2.4 Update function

As particles are swarming in free space its velocity and position are changing. New velocities and positions for each particle are calculated. The velocity of a particle is updated using eq. 16

\[ V_{id}^{t+1} = w \times V_{id}^t + c_1 \times r_1 (p_{id}^t - q_{id}^t) + c_2 \times r_2 (p_{gd}^t - q_{gd}^t) \]  

(16)

The velocity update equation has three major components-

- **First component** - is “inertia”, “momentum” or “habit” denoted as W. It frames the tendency of the particle to continue in the same direction in which it travels. The selection of W provides a balance between global and local explorations. This factor is vital for convergence of the algorithm. It also prevents impacts of the previous velocity on the current one. In proposed method, we consider the value of W as 4.

- **Second component** -of update function gets from linear attraction towards the best position ever found by the given particle p_{id}^t. This is scaled by a random weight C_1 and R_1. C_1 determines trust between the global and local best. The value of C_1 is considered either 0 or 1. The larger the value of C_1 more particles will be placed around the global best. The product of C_1 and R_1 is considered as the cognitive parameter. This component is identified as “Nostalgia”, “Memory”, or “Remembrance”, or “Self- knowledge”

- **Third component** - is the linear attraction towards the best position found by any particle p_{gd}^t. p_{gd}^t is scaled by random weights C_2 and R_2. The C_2 range is also
kept between zero and one. It establishes the point between global and local best that is a standard deviation from both. The product of $C_2$ and $R_2$ is considered as a social parameter. This part also is known as “Co-operation”, “social knowledge”, “group knowledge” or shared information. The velocity and weight of the particle increase till maximum iteration is reached.

2.5 Allocation

Using graph coloring theory array of information is collected and is normalized using PSO. For each solution by considering the priority of cognitive users and availability of spectrum, Comprehensive value spectrum is allocated for that particular user. When primary and secondary network is in small location special reuse of the spectrum is done. The value of velocity and position are updated till optimized solution or until maximum iteration. The outcome is the allocation of spectrum for a particular channel. The top paid demanding users are allocated initially.

2.6 Entire network reward:

It is nothing but network benefits resulting from spectrum allocation based on users demand. $NR_{\text{max}}$ represents the sum of all users’ network rewards included in MMR (Maximum minimum reward). Each primary user can get some reward value after selling its spectrum. $NR_{\text{max}}$ is network benefits after spectrum allocation. It is nothing but the sum of all users reward transmitting with the particular channel.

$$NR_{\text{max}} = \sum_{i=1}^{N} \sum_{j=1}^{M} (Z_{i,j} \times C_{i,j})$$ (17)

2.7 Fairness reward

Many times, the criteria for maximizing the network throughput can create unfairness in spectrum distribution among secondary users. This unfairness means that one user can select multiple channels and others are left with no available channel. By using several utility functions, work has been done for maximizing fairness. The increasing fairness means assigning channels to secondary users by considering centralized approach aiming at achieving the fair distribution of spectrum. It is used to check resource that a user obtains in one allocation size compared with the resource allocated to other users means to check whether it is fair in the context of an entire network. The increase in this function indicates that user has obtained similar spectrum resource and outcome in better fairness rating of the network. If network is not fair enough then entire network reward get lower [28].
The pseudo code is shown in Table 1.

Table 1: SODA_PSO algorithm

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>Solution of the particle</td>
</tr>
<tr>
<td>Velocity</td>
<td>Velocity of the particle</td>
</tr>
<tr>
<td>P_best</td>
<td>Individual best fitness value</td>
</tr>
<tr>
<td>G_best</td>
<td>Global best fitness value</td>
</tr>
<tr>
<td>Y</td>
<td>Interference matrix</td>
</tr>
<tr>
<td>X</td>
<td>Availability matrix</td>
</tr>
<tr>
<td>B,P,A,Δ</td>
<td>Subset reward matrix</td>
</tr>
<tr>
<td>W1,W2,W3</td>
<td>The weights for the audio, video and data users</td>
</tr>
<tr>
<td>Weight</td>
<td>The weight for the PSO</td>
</tr>
</tbody>
</table>

Startup()
Initialize conflict graph by noofc, noofp, range of channel frequency;
Turn to GCP function();

GCP()
Establish GCP network;
Initialize X,Y,Z according to graph theory;
Initialize B,A,P,Δ;
Initialize service type matrix randomly;
Turn to Reward normalization();

Reward normalization()
Normalization of all of the sub rewards based on service types defined by Matrix Δ;
If it is Audio user
\[ C_{ij} = w_1b_{ij} + w_2p_{ij} + w_3a_{ij} + w_4Δ_{ij} \]
If it is Video users
\[ C_{ij} = w_1b_{ij} + w_2p_{ij} + w_3a_{ij} + w_4Δ_{ij} \]
If it is Data user
\[ C_{ij} = w_1b_{ij} + w_2p_{ij} + w_3a_{ij} + w_4Δ_{ij} \]
Turn to Priority function();

Priority Function()
Estimation of priority based on Δ;

\[
\text{Fairness} = \left( \prod_{i=1}^{N} \left( \sum_{j=1}^{M} (Z_{i,j} \cdot C_{i,j}) + 1 \cdot 10^{-6} \right) \right)^{1/N} \tag{18}
\]
3. Simulation:

3.1 Setting the assessment scenario

The evaluation of network performance is done through MATLAB simulations. The network scenario of primary and secondary users is generated in a 1200 * 1200 area using MATLAB functions. Graph of users are generated using MATLAB. For network creation M, N is considered as 8 and 10 respectively. There are gold, silver, copper and red cognitive users present, having their cost compensation and demand for allocation. It is shown in Fig. 4 where channels are assigned randomly and occupied by primary users with interference region radius of 100. The minimum and maximum interference of cognitive users are set as 1 and 4 respectively.

Based on priority turn to Allocation Function();

Allocation Function()
Initialize the particle in solution space as noofc;
For each particle Consider comprehensive value;
Maximise comprehensive reward;
Calculate Local and Global cost;
If cost value is better than( Pbestj in history;
Set current value of position as the new Pbest;
End
Set best value of Pbest as the Gbest global value;
Reduction of the weight value until the maximum iteration;
For each particle
Update velocity;
End
If the maximum iteration has not reached
Turn to Allocation function();
The preference weight for different sub-reward is set according to service type shown in Table 3. Weights $W$ are followed by two constraints.

\begin{align}
0 \leq W_i \leq 1 & \quad \text{for } i=1, 2, \ldots, N \\
\sum_{i=1}^{N} W_i &= 1
\end{align} \tag{19} \tag{20}

For multiple objective weights are selected based on preference for specific multi-objective for service type. The summation of weights should be 1. Weights shown in Table 3 are assumptions of authors. According to relevant data transmission demands of wireless communication network parameters are set. The channel bandwidth range will be from 10 kbps to 1000 kbps and availability of channel is from 0 to 1. The service type of users’ are randomly decided. The specific range is initialized for three service type as shown in Table 2.
Table 2: Throughput values

<table>
<thead>
<tr>
<th>Service type</th>
<th>Range of throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>512 Kbps</td>
</tr>
<tr>
<td>Video</td>
<td>64-32.4 Kbps</td>
</tr>
<tr>
<td>Audio</td>
<td>8-32 Kbps</td>
</tr>
</tbody>
</table>

The performance of the algorithm is evaluated by networks overall rewards by selling spectrum and fairness. The evaluations indicators are assumed as entire network reward based on the demand of users and network fairness. Common comparisons are made with these two.

Table 3: Preference weights for decision parameters

<table>
<thead>
<tr>
<th>Service type</th>
<th>Bandwidth reward</th>
<th>Transmission power reward</th>
<th>Availability reward</th>
<th>Throughput reward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio</td>
<td>0.3</td>
<td>0.15</td>
<td>0.25</td>
<td>0.3</td>
</tr>
<tr>
<td>Video</td>
<td>0.35</td>
<td>0.1</td>
<td>0.25</td>
<td>0.3</td>
</tr>
<tr>
<td>Data</td>
<td>0.25</td>
<td>0.25</td>
<td>0.1</td>
<td>0.4</td>
</tr>
</tbody>
</table>

After optimization spectrum is allocated to secondary users which are having lower fitness function means it has high priority for allocation. After allocating users to each channel next secondary users having high priority can use channel based on availability and interference matrix. Here a criterion of frequency reuse is used. Each base station has its specific range. In wireless mobile system bandwidth is divided into number of channels. Channels are allows to used by number of users based on minimum reusable distance. Proposed system allows more than one user same frequency based on final optimization result. The allocation results are shown in Fig.5.
3.2 Evaluation of Results and Analysis

3.2.1 Impact of the number of channels:

This scenario includes 30 primary and 15 cognitive users. The available channels range from 5 to 30. The simulation results are shown in Fig. 6 and Fig. 7, where as the number of channel increases, the users can obtain more spectrum resources. This subsequently increases the network reward and the fairness between the users becomes stable. The three utility functions namely Max-Sum reward (MSR), Max-Min reward (MMR), Max-Proportional fairness (MPF) increases. The proposed algorithm is service oriented i.e. it considers service types so as to achieve better comprehensive reward than other algorithms. Normalizing values obtained from eq.
17 and 18 graph is plot. For different graph different values we get and plot may be different.

![Network Reward](image1)

**Fig. 6.** Network reward vs Number of channels.

![Fairness Reward](image2)

**Fig. 7.** Fairness reward vs Number of channels.

### 3.2.2 Impact of the number of cognitive users

Figure 8 and 9 shows the variation of Network reward and fairness reward with a number of secondary or cognitive users. As a number of cognitive users or user density increases, more interference constraints are created. The range of the cognitive users is selected from 10 to 60. The number of cognitive users increases for a set number of available channels, the spectrum resources decreases to it. So the
entire network reward decreases and competition for resources between the users strengthens resulting in the decrease in fairness. In this condition, spectrum resources will allocate spectrum resources to the previous cognitive users’ for better network reward without considering the fairness between the users’. Based on the calculated rvalues from eq. 17 and 18 these graphs are obtained.

**Fig. 8**: Network reward Vs No. of Secondary users

**Fig. 9**: Fairness reward Vs No. of Secondary users
3.2.3 Comparison with existing methods:

The proposed system is compared with the existing system [28] where Dynamic Spectrum Allocation is accomplished without inputs from learning algorithms. The results of Multi-Objective Based and Service Oriented-PSO and DSA-PSO values are compared with proposed method. The proposed system achieves greater network rewards and fairness with a respective number of channels and cognitive users. All cognitive users get the benefit of using spectrum channel and hence the overall network reward increases. The fairness cannot be affected by the increase in the number of channels. The proposed system has high fairness value as compared to other systems because there are very few cognitive users for which there are no available channels. The comparison of results is shown in the figure.10, 11, 12, and 13. The proposed method considers all spectrum resources which makes it more beneficial. The complexity of the proposed algorithm is less and it is more stable than existing methods. The comparison result is the mean value of the 30 stimulation results.

![Network Reward](image)

Fig. 10: Comparison of Network rewards Vs Number of channels
Fig. 11: Comparison of Fairness Reward Vs Number of channels

Fig. 12: Comparison of Fairness reward Vs Number of cognitive users

Fig. 13: Comparison of Network reward Vs Number of cognitive users
4. Conclusion

The application services have mushroomed in modern wireless network industries. Taking into account type of cognitive users service, development of allocation algorithm which is multi-service based is highly important to overcome the problem of deterioration which results from deficient matching between user’s demands and spectrum resources. These problems result in inefficient spectrum utilization. To overcome these problems along with problem-related to spectrum allocation Service Oriented Multi-Objective Based PSO algorithm incorporating inputs from learning algorithms is presented in this paper, based on GCP and PSO methods. It comprehensively considers spectrum characteristics like bandwidth, the noise, channel availability, throughput, and others to satisfy users’ service demands. The priority of cognitive users is also considered. Based on prize and demand of spectrum users, spectrums are allocated. As illustrated in results the proposed algorithm can obtain enhanced network reward and fairness with good iteration efficiency. When multiple Cognitive users are involved, the proposed method works better than existing algorithms. The multi-objective decision method considers various characteristics attribute. It is developed to obtain a more comprehensive reward with respect to users’ demands. Along with these characteristics, cognitive users throughput values are considered for allocation process and based on priority the user’s service demand is fulfilled. Spectrum is efficiently allotted to users with better efficiency and fairness with more stability in performance than existing methods.

References


