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Implementation of Resource Allocation Algorithm for Cognitive Radio Systems

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Abstract: Due to the increase in communication techniques, Radio spectrum has become a scarce resource. Based on the information available from the spectrum in the area, Cognitive Radio (CR) networks determine the usage of bandwidth by adjusting its transmission. It automatically detects the usage of the spectrum and decides how to use the available resources. Few newly adapted devices try to utilize the unused spectrum which is the main idea behind the cognitive radio network working. It can transmit signals according the noise, interference and variations in the channel. When the channel will be idle, that will be sensed by the CR and it tries to allocate that spectrum to some user in need. CR operation is completely based on the SDR. Here we are using optimization technique based on evolutionary algorithms to utilize the available resources and to allocate them to the users in need. Here the evolutionary algorithms used are particle swarm optimization (PSO), Modified PSO (MPSO) and kinetic gas molecular optimization (KGMO). We have simulated subcarrier allocation and power allocation of all three algorithms and checked which algorithm helps in better resource allocation. Simulation results also show capacity of each user and also comparing with other algorithms.

Keywords : Cognitive radio, KGMO, MPSO, PSO Optimization techniques.

I. INTRODUCTION

Radio spectrum has become a rare resource due to the rapid development of communication technique in wireless domain. Cognitive radio is one of important techniques to deal with this radio spectrum problem [1]. The spectrum sharing has a major problem with the primary users and the secondary users, and carried out the centralized spectrum allocation with few parameters is discussed in [2]. But the resource allocation in cognitive radio also has its own issues, such as the flexibility of the allocation algorithm, the performance of resource allocation, and so on. Therefore to increase the flexibility in the allocation algorithm for cognitive radio, more and more researches are focusing on the evolutionary algorithms [3]. Evolutionary algorithm can greatly improve the flexibility of the allocation algorithm for cognitive radio system in different communication scenarios, but the performances are relatively lower than the original mathematical methods.

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Researchers focussed on the number of algorithm present namely Genetic algorithm (GA) and PSO. The resource allocation method which is adaptive to the spectrum is proposed based on modified PSO (MPSO) which helps cognitive system to solve the problems of PSO and GA. MPSO has both GA and PSO's updating processes which makes this modified PSO overcame PSO's own disadvantages and keep advantages. Simulation results show that proposed algorithm has enough flexibility to meet cognitive radio systems' requirements, and also has a better performance than original PSO. We also used another adaptive resource allocation algorithm i.e., KGMO which uses kinetic energy of the gas molecules for optimization of resource allocation and this algorithm gives better performance than other algorithms mentioned. Simulation results show the comparison between PSO, MPSO and KGMO and also capacity of each user in the system.

According to the concept of cognitive radio system, utilization of the spectrum will be greatly increased by allowing the SUs access the spectrum bands which are licensed and allocated to PUs (primary users) by government [4]. Adaptive resource allocation is an important part in cognitive radio system, transmitted power and management of dynamic spectrum is one of the three basic minor works of the system mentioned. Comparing with resource allocation algorithm in current communication system, as an important part of cognitive radio, resource allocation algorithm in cognitive radio system is focusing on adaptive resource allocation ability, flexibility of the algorithm and the allocation performance [5]. More and more researchers put evolutionary algorithm into consideration, because these evolutionary algorithms have great adaptability and flexibility.

But evolutionary algorithm has its own problems, such as low convergence speed and lack of global searching ability [6]. To deal with the problems discussed, in this paper, a modified adaptive resource allocation algorithm for cognitive radio is proposed, that is combined with particle swarm optimization and genetic algorithm's advantages, also added a learning scheme into this proposed algorithm in order to deal with certain fast allocation speed needed situations. Results that are obtained through simulation proves that the proposed algorithms has better performance both in global searching ability and convergence speed. The comparison graph shows that one algorithm has better performance than other. Researchers have come up with many algorithms which help in allocating resources to the users in cognitive radio. Few algorithms are attempted in this paper to check for better allocation results obtained.

The remaining paper is divides as mentioned below. In Section II, we described the overall description of the system and mathematical model.

Then, PSO based allocation algorithm is described in Section III. Modified PSO based adaptive allocation algorithm of the resources is discussed in Section IV. Another algorithm KGMO is explained in Section V. In Section VI, we verify our proposed algorithm's flexibility, and compare all three algorithms. Extensive simulations and discussions are provided to demonstrate the effectiveness of our approaches in Section III, IV and V, followed by the conclusions.

II. SYSTEM MODEL

In the paper, we considered the cognitive radio based on an OFDM communication system [7], and designed design model used is shown in Fig 1. There are K SUs that need to be considered simultaneously and N number of subcarriers, and congestion problem isn't under consideration, which means $K \leq N$ in this paper. Resource allocation algorithm allocates a sub requirement of N carriers taken for design to allowed user and describes the transmission power for particularly assigned given subcarrier on downlink transmission. ρk ,n is a discrete binary number for the value of [0,1], Ωk represents the number of subcarriers that are allocated to SU k, then

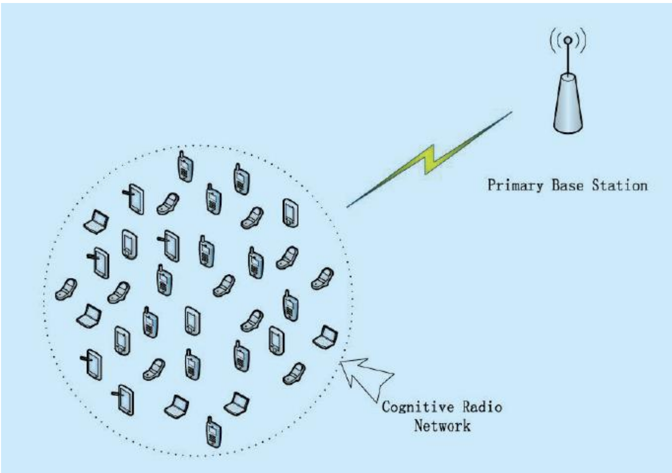


Fig. 1. System model

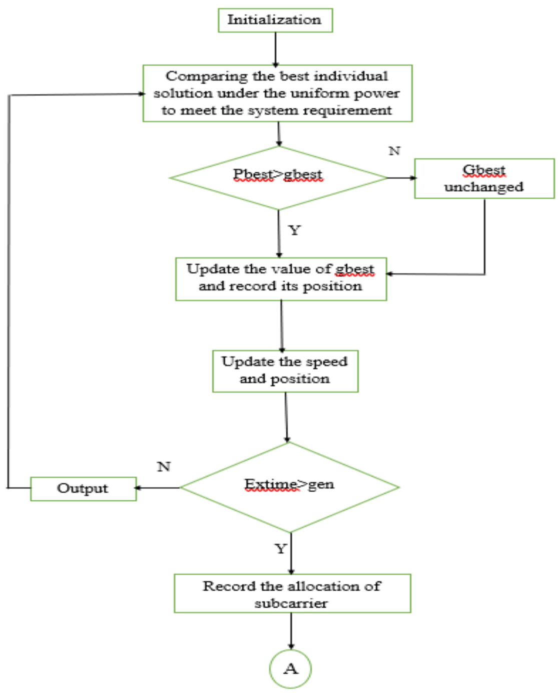
$\rho kn = \begin{cases} 1, & n \in \Omega k \\ 0, & n \, ! \in \Omega k \end{cases}$; N0 is the additive Gauss white noise (AWGN) power spectrum density; Besides the total transmit capacity, uses' fairness is also important. Fairness among users in communication systems is one of the most important indicators of system performance [8]. Guaranteeing fairness among users in the system enables users farther away from the base station to enjoy the same QoS as other users during resource allocation. At the same time, dynamic adjustment of user fairness is also one of the goals of dynamic regulation such as access control and load balancing [9]. For the design of the system, 6 constraint conditions should be considered. They are

- The transmission power of each user in the system cant exceed the total transmission power limit required by the system.
- The transmission power of each sub carrier in the system is positive.
- Each subcarrier of the communication system in one distribution can only be allocated to one user, and there cant be a subcarrier to be assigned to two users at the same time. This covers constraint 3 & 4.
- The error rate of each user in the system cant exceed the minimum BER requirement of the business [10].
- Fairness constraints between users in communication systems.

There are two types of resources in the allocation allocation problem that need to be addressed: subcarrier allocation and transmit power. Subcarrier is an integer variable, and the transmit power is a typical nonlinear two layer mixed integer programming problem. Hence to simplify the problem, the entire process of allocation is divided into 2 parts: that is subcarrier and power allocation. Allocation of the Subcarriers are based on average power pre-allocation, and allocating of the power will be based depending on the results of allocating of the carriers. The flowchart for the allocation which applies to all three algorithms is as shown in fig. 2.

III. PSO ALGORITHM

Molecule Swarm Optimization (PSO) is a swarm-put together strategy centered with respect to taking care of enhancement issues. It depends on swarm knowledge and draws on the conduct of winged creatures, who constantly disperse to various areas when they begin looking for nourishment. Contingent upon their present area, they attempt to follow nourishment sources. Fowls nearer to the source can distinguish the source and convey this data to different feathered creatures with the goal that they can draw closer to the source. Subsequently, after various such developments the winged creatures will gather to the nourishment source. The participation between the flying creatures could be basic for describing arrangement.



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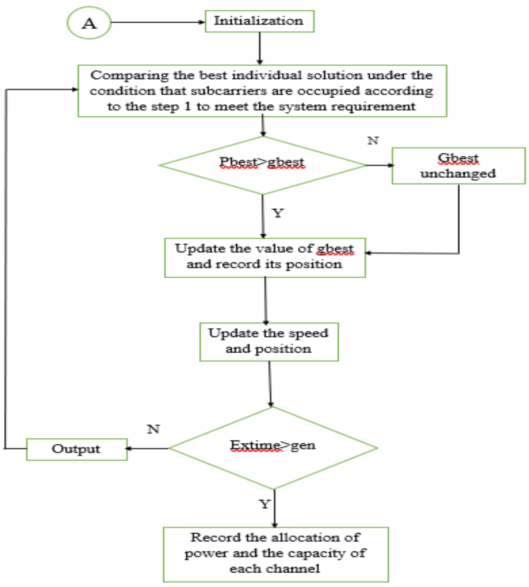

Fig.2 Flowchart for resource and power allocation

The PSO technique copies the conduct of fowls in the figuring domain to look for ideal arrangements over huge spaces. It utilizes a populace of particles, speaking to winged creatures, which start aimlessly positions and discover their closeness to the arrangement by assessing a very much characterized wellness work. Every molecule discovers its neighborhood best place or the position, and the worldwide important situation among the molecules is resolved. In light of these qualities, the speeds of the flying creatures are chosen, the required places are gotten utilizing the speeds mentioned. The circumstances of the nearby molecule and the overall less distance positions guarantees the relation between them and trade of data between the molecules and furthermore ensures the particles will be guided nearer to the arrangement with all progression. The molecules/particles in the group unite to the arrangement by rehashing the means till little halting criteria are achieved.

Coming up next is a general calculation of PSO.

1 Start with the populace with arbitrary distances and speeds
2 Obtain readiness for each and every particle.
3 Obtain the individual nearer (pbest) for singular distances and worldwide nearer (gbest) for overall particles
4 While halting criteria isn't completed
5 Design speed for all particles using Eq. (1)
6 Reuse the places of particles used using Eq. (2)
7 Obtain the qualification for every particle.
8 Check whether wellness esteem for molecules are better than its nearer one.
9 Repeat pbest with obtained present wellness
10 End if done
11 Else obtain overall best one among all particles
12 End this when the search is completed.

The distance and the speed of the molecules here are determined as mentioned:

$$V_i^{new} = w * V_i^{old} + a_1 * r_1 * (pbest_i^{old} - P_i^{old}) + a_2 * r_2 * (gbest_i^{old} - P_i^{old}) \quad (1)$$

$$P_i^{new} = P_i^{old} + V_i^{new} \quad (2)$$

In these conditions, Vi old is the speed of ith molecule in the past age, Vi new is the speed of ith molecule in the present age, Pi old is the situation of ith molecule in the past age, Pi new is the situation of ith particle in the present age, a1 and a2 are quickening fac-tors of neighborhood and worldwide data individually, r1 and r2 are arbitrary qualities somewhere in the range of 0 and 1, w is the idleness weight. Every molecule speaks to a particular portion of clients to bearers. The wellness of every molecule is discovered. In the wake of discovering nearby particle and overall obtained one for every molecule, the recent speeds will be determined and the distances refreshed. The used procedure is rehashed until end to get overall allotment is found, for example the portion which provides most extreme all out exchange rate, under the predefined limitations of less mistake requirement, singular exchange rate and absolute force use. The flowchart in Fig. 4.1 speaks to the means of the proposed system. Higher exchange rate is acquired with a quicker execution time by following the proposed approach utilizing PSO calculation when contrasted with different calculations, for example, GA. The proposed approach combines at around 60 cycles which makes it a quick and productive methodology. This is because of the way that the particles share the data among them, accordingly making each emphasis more ideal than past one.

IV. MPSO ALGORITHM

Modified particle swarm optimization (Modified PSO) has both genetic algorithm (GA) and particle swarm optimization (PSO)'s updating processes which makes this modified PSO overcame PSO's own disadvantages and keep advantages. According to the concept of cognitive radio system, spectrum utilization can be greatly improved by letting the SUs (secondary users) access the li- censed spectrum bands which allocated to PUs (primary users) by government. Adaptive re- source allocation is an important part in cognitive radio system, transmit-power control and dynamic spectrum management is one of the three fundamental cognitive tasks of cognitive radio. Comparing with the resource allocation algorithm in current communication system, as an important part of cognitive radio, resource allocation algorithm in cognitive radio system is focusing on adaptive resource allocation ability, flexibility of the algorithm and the allocation performance. Evolutionary algorithms have great adaptability and flexibility. But evolutionary algorithm has its own problems, such as low convergence speed and lack of global searching ability. To overcome this, Modified PSO algorithm is used which givers faster convergence speed and has better performance in global searching ability.

we consider the cognitive radio system is based on an OFDM communication system. There are K SUs want to be served simultaneously and N subcarriers, and congestion problem isn't under consideration, which means $K \leq N$ in this paper. Resource allocation algorithm allocates the values for N number of carriers to the allowed member and finds the transmission power for every allocated carrier value on lower transmission. ρk ,n is a discrete binary number for the value of [0,1], Ωk denotes the set of subcarriers are allocated to SU k, then

$$\rho_{k,n} = \begin{cases} 1, & n \in \Omega k \\ 0, & n \notin \Omega k \end{cases} \quad ; N_0 \text{ is the additive Gauss} \quad (3)$$

white noise (AWGN) power spectrum density; Besides the total transmit capacity, uses' fairness is also important. Fairness among users in communication systems is one of the most important indicators of system performance. Guaranteeing fairness among users in the system enables users farther away from the base station to enjoy the same QoS as other users during resource allocation. At the same time, dynamic adjustment of user fairness is also one of the goals of dynamic regulation such as access control and load balancing. There three parts in these process of mpso. The first one is selection. We randomly choose two particles in the particle group. The second one is crossover. Selected particles exchange their information by half. The last one is mutation. Information of new particles created by the second part can mutate by probability p2. Besides that, we also add a data-base into this modified PSO based resource allocation algorithm to meet some fast allocation time required communication scenarios. Original PSO always starts the optimization process with a group of totally random particle. This process can keep the group diversity high enough to maintain the global searching ability. But in practical, if we start the optimization with particles which are not completely random but from the similar particle scheme data in data-base, then the whole allocation time will be greatly reduced.

The number of particles represents the number of subcarriers, and each particle's content is user's index which means this user is allocated to the subcarrier and also the number of particles represents the number of the subcarriers, and each particle's content is transmit power which means this amount of transmit power is allocated to the subcarrier. To utilizing the adaptive ability of cognitive radio system, cognitive radio system could be deployed in different scenarios and also could change from time to time. So there are three communication scenarios are taken into consideration: 1. Multi-users' unicast service. 2. Multi-users' multicast service with low data rate. 3. Multi-users' multicast service with high data rate. These three scenarios have different requirement to meet for resource allocation. In scenarios 1, the system requirement is to maximize the total capacity, and total transmit power and user's fairness issues are seen as two constraints. In scenarios 2, the system requirement is to keep users' capacity as fair as possible with total transmit power limitation as a constraint. In scenarios 3, the system requirement is maximize the lowest user's capacity with total transmit power limitation as a constraint. The procedure of this allotment allocation has two sections: one is subcarrier portion; the other one is power distribution. We need to ensure all the customers can utilize the channel at a moderately even level, so Pi = Ptotal/k , Ptotal is the absolute force limitation.

• Initialization: Initialize molecule plan, position and speed.
• Comparing with the best individual answers for locate a best subcarrier distribution molecule to meet the framework prerequisite. (Uniform force is a suspicion, and force assignment is in the subsequent part; System necessity: it is diverse in various situations.)
• If there is preferable molecule over the best molecule ever, at that point update it.
• Particles update : refreshing particles' position and speed.
• Output : Based on the principal assignment's outcome, the subsequent part power portion starts.

In the subsequent part, as the mapping among clients and subcarrier is settled, improvement of transmission power is finished.

• Initialization: load the aftereffect of the initial segment designation. Instate molecule conspire, position what's more, speed.
• Comparing with the best individual answers for locate a best force portion molecule to meet the framework prerequisite. (Subcarriers have just been dispensed to every customer agreeing the arrangement of subcarrier portion part. Framework prerequisite: it is distinctive in various situations.)
• If there is preferred molecule over the best molecule ever, at that point update it.
• Particles update
• Output

V. KGMO ALGORITHM

The calculation of this algorithm must have the option to accomplish an answer that has the least (or probably, a little) mistake contrasted and the comprehensively ideal arrangement inside an insignificant number of emphrases, in this manner offering an improvement as far as exactness, intermingling ways and straightforwardness of activities. The required improvement calculation that will be required is, the Kinetic Gas Molecule Optimization, which depends entirely on the working pattern of the atoms present in the space. The presentation with the mentioned calculation will be assessed within two notable improvement calculations. This can be indicated with the obtained gas atom conduct model can accomplish progressively exact outcomes along the littler average Square value needed and in fewer emphasess, contrasted and the benchmark calculations.

The nuclear hypothesis of gases expresses that every substance is made out of an enormous number of extremely little particles (atoms or molecules). Essentially, the entirety of the essentials of molecules, along with the weight, area and heat, will be the outcome for activities with the atoms which makes gases. Mentioned are five hypothesizes which portray conduct of atoms in gases used. Dynamic atomic hypothesis of perfect gas are mentioned below:

1. It comprises of an assortment for little particles (atoms) with movement in single path movement. The development depends on many laws to be considered as newtons.
2. A gas requires no volume when the particles are used which are focused.
3. Impacts within particles are flawlessly flexible. No vitality is picked up or lost when it is throwed.
4. The alluring or horrendous powers between the particles does not present.
5. Normal active vitality of particle is 3kT/2, which has T as the outright heat, and k is the constant value steady, where the estimation is 1.38 × 10—23.

The rule used for gas molecules is: PV = NKT (4)

where P defines pressure expelled og gas, V the total volume, and N is the maximum particles considered.

The energy which defines kinetic base is given by:

$$\Delta k = w = F\Delta s = ma\Delta s \quad (5)$$

Among which Δk denotes distinction of gas particle's motor vitality within the recently used and present values, w denotes vitality used, F denotes power utilized, Δs denotes distinction with places of atoms in a single time interim, and m defines weight of the particle in space. It is realized that gas particles draw information which depends on powerless molecular Van Der powers which are among one another, where power is the consequence of required and unnecessary charges in present atoms. In this method, every ga atom (specialist) has four details: position, motor vitality, speed and mass. The dynamic vitality of every ga atom decides its speed and distance. Compared with calculation, the present atoms investigate the entire hunt area to arrive at the point that which defines reduced temperatire. Now, use a framework which uses many operators (atoms). The ith specialist value is characterized by

$$X_i = (x_i^1, \ldots, x_i^d, \ldots x_i^n), \quad \text{for } (i = 1, 2, \ldots, N) \tag{6}$$

where xdi mentions the distance of ith value from dth value. The speed measured for the ith moment is:

$$V_i = (v_i^1, \ldots v_i^d, \ldots, v_i^n), \quad \text{for } (i = 1, 2, \ldots, N) \tag{7}$$

here vdi denotes the speed of the agent with max values. The molecules of the gas moves within the area of the movement of the gas molecules in the cylinder is given here, that indicates that speed is proportional to exponent values of the molecules' calculated energy. The energy obtained, is then given as

$$k_i^d(t) = \frac{3}{2} NbT_i^d(t), K_i = (k_i^1, \ldots k_i^d, \ldots, k_i^n), \quad \text{for } (i = 1, 2, \ldots, N) \tag{8}$$

here N denotes quantity of atoms, and Tdi(t) is the present temp in the space for ith specialist in the dth measurement at given time.

Every particle endeavors to alter its position (xdi) by utilizing the separation between the present position and pbestdi and the difference among the present value obtained and calculated one. The strides in the system calculation are outlined by pseudocode as mentioned:

For every particle {
Repeating initialization of gas particles till it fulfills all requirements
}
Do {
For every molecule {
Compute wellness esteem
On the off chance that the determined wellness esteem will give maximum result compared to current wellness esteem OR no current best value {
Incentive as the new value obtained is set }
}
every molecule loops as { In the event that molecule's present value to be greater than the worldwide wellness esteem up until this point OR current gbest does not come{
Molecule's present near particle is set as greater best particle}
Compute the dynamic vitality for every ga particle (Equ. (6))
molecule speed will be updated} }
while most extreme cycles or least mistake paradigm not accomplished.

VI. SIMULATION RESULTS

Simulation results allocated by PSO, modified PSO and KGMO are compared with same number of parameters and testsets. All the simulation results meet the systems' requirements, which show that proposed algorithms can deal with multiple communication scenarios with great flexibility and one algorithm gives better performance than other. The capacity of each user is plotted in all the three cases. Power and Resource allocation are compared and it is shown that KGMO gives better results than other two. These algorithms are used for optimization of the resource allocation methods for cognitive radio. The allocation algorithms also provide effective flexibility guarantee for cognitive radio in decision making, and a powerful theoretical support for the cognitive radio system to further improve the spectrum utilization. Because of adding crossover and mutation in modified PSO based allocation algorithm, modified PSO has a higher global searching ability and relatively lower convergence rate. The group diversity is increased. The resource and power allocation comparison for all three is shown in figure 3 and figure 4 respectively. In the figures we can make out that the convergence speed is faster for the Kinetic related algorithm which is nearly 20. That is, for 20 iterations the resources are allocated to the users, whereas it is nearly 50 for modifies pso and 100 for normal pso. Hence we can say that kgmo has higher convergence speed and also allocated more resources, hence one of the best optimizing technique. Similarly for power allocation, the kgmo has convergence speed which is nearly ideal. Remaining two algorithms give normal result which r quite similar.

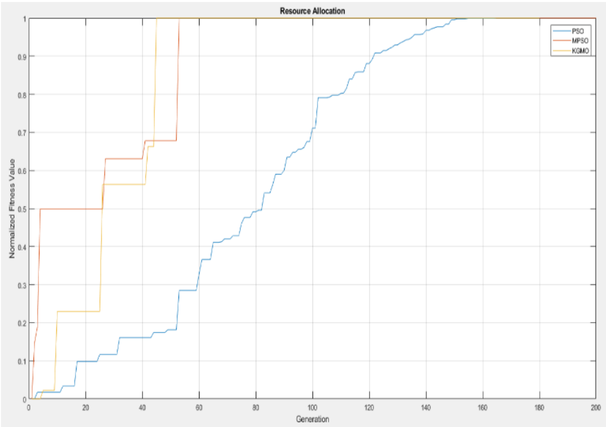

Figure 3: Comparing algorithms for resource allocation

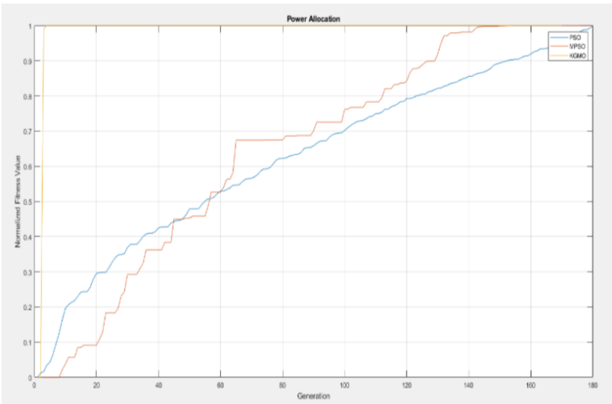

Figure 4: Comparing algorithms for power allocation

VII. CONCLUSION AND FUTURE SCOPE

Therefore to increase the flexibility of cognitive radio results in resource allocation algorithm, evolutionary algorithm as the core of the allocation algorithm are adopted. However, because the evolutionary algorithm is easy to fall into the local optimal solution and can't achieve the global optimal problem in the allocation results, we proposed a cognitive radio adaptive allocation algorithm for the resources will be obtained for the improved swarm optimizing algorithm.

The proposed mPSO has the advantage being used using both particle swarm optimization and genetic algorithm by adding genetic algorithm's mechanism into particle swarm optimization. Proposed algorithm also has great flexibility to fit cognitive radio's adaptive tasks in different communication scenarios. In the structure of the resource allocation algorithm, we decompose the whole allocation process into two sequential optimization problems, and verify the flexibility of the allocation for the resources using algorithms mentioned. Simulation results shows that one algorithm has a better allocation performance than another one as such PSO and all three fitness functions can match these three systems' requirements well. At last, the modified PSO and the standard PSO have done a lot of simulation experiments in the resource allocation problem. The graphs show that the used algorithms ensures the flexibility and also has a better resource allocation results.

The second proposed algorithm KGMO gives better performance than the PSO, GA and MPSO since it uses the kinetic energy of the gas molecules for optimization. Hence simulation results show that the proposed algorithm has better resource allocation and power allocation. The flexibility of the algorithm is higher and the capacity of the users are plotted through bar graph. Thus we can come up with other better algorithms which has higher convergence speed, greater flexibility and gives better optimization. An algorithm which overcomes the disadvantages of all the previously mentioned algorithms can be think of which will be the future scope in this regard.

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