User Based Scheduling and Resource Allocation in Downlink OFDM System with PSO and GA

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***Abstract*— Proficient allocation of resources like bandwidth, bit and power to the users is essential due to the inadequate resources available at the base station. A novel technique for scheduling and resource allocation in multiuser OFDM system is proposed here. For scheduling, switched based scheduling and on/off based scheduling techniques are used to schedule the users. The quality users based on threshold SNR from the scheduler are optimized in the PSO-GA optimizer. In the optimizer the subcarrier and power allocation are carried out suboptimally. The adaptive resource allocation is considered for three scenarios such as multiuser unicast service, multiuser multicast services at low and constant rate and multiuser multicast services at high rate. Simulation results show that the combination of PSO and GA with scheduling yields better results than normal PSO and considerable reduction in BER and improvement in average spectral efficiency.**

Keyword- Adaptive resource allocation, orthogonal frequency division multiplexing (OFDM), scheduling, average spectral efficiency (ASE), bit error rate (BER)

I. INTRODUCTION

OFDM is a multicarrier modulation and multiplexing technique. The resource allocation in OFDM is classified as static and dynamic allocation. TDMA, FDMA are static allocation methods. In TDMA the time slots are predefined but in FDMA the frequency bands are predefined. The allocation in TDMA and FDMA are fixed irrespective of the current channel conditions. In adaptive resource allocation method, rate adaptive (RA) and margin adaptive (MA) methods are available. MA technique supports in minimizing the total transmit power [1] and RA method is used to maximize the total throughput of the system [2, 3].Ideal proportional rate distribution is considered in [4]. A lower complexity algorithm has been formulated to achieve resource allocation [5]. A priority based sequential scheduling is used to enhance system capacity with reduction in fairness [6]. Tradeoff between capacity and fairness is deliberated in [7]. A joint power and subcarrier allocation is dealt in [8] and RA scheme is used with fairness among users. The resource allocation problem for multiuser OFDM is considered for cognitive radio systems in [9] to maximize the sum capacity with fairness.

In this paper Scheduling and resource allocation are considered for downlink transmission in an OFDM based wireless network. An optimal dual solution is developed for downlink scheduling and resource allocation in OFDM systems along with gradient based approach [10]. Scheduling and resource allocation is jointly considered for uplink OFDM systems with the gradient based technique along with dual optimization [11]. Multiuser scheduling like absolute SNR-based scheduling, normalized SNR-based scheduling, SBS and OOBS schemes are considered in detail [12]. The switched diversity based schemes paved the way for the development of SBS scheme [13, 14]. Average Spectral Efficiency (ASE) is increased due to the adaptation of threshold-based power allocation algorithms like SBS in scheduling [15].GA is used to allocate resources adaptively in multiuser OFDM [16]. GA and PSO are used to do the subcarrier and bit allocations, where MA technique is used [17]. Two evolutionary approaches like differential evolution (DE) and PSO are applied for carrying out the resource allocation [18] where RA technique is used.

For the downlink scenario, the base station collects the channel SNRs corresponding to all users to select the best user for data transmission. The selective multiuser diversity scheduling scheme is combined with resource allocation. The users are decided by the threshold value and later the identified users are allocated with subcarriers with the corresponding power. Scheduling algorithms are introduced to improve ASE.

Two scheduling schemes combined with adaptive resource allocation are proposed in this paper. The resource allocation is considered for three different scenarios namely multiuser unicast services, multiuser multicast services at low and constant rate and multiuser multicast services at high rate. In the existing work, resource allocation for the available users is carried out with respect to total capacity and it is implemented using hybrid

PSO optimizer [19]. The BER criterion is not taken for analysis, since the paper focuses on achieving best power and good channel allocation. Two scheduling schemes based on threshold namely OOBS and SBS are considered here. Users that are below the threshold are completely ignored, because their SNR values are below threshold results in poor utilization of channel [20]. In turn it affects the ASE. In order to increase ASE and to improve the channel capacity, SBS were derived [21].SBS scheduling scheme with PSO-GA used to acquire maximum channel capacity with reduction in BER.

The paper is organized as follows. Proposed approach is described in section II followed by the proposed system model discussions in section III. Optimization problems in three scenarios are considered in section IV. In section V, scheduling and optimization concepts are presented. Simulation results are presented and discussed in section VI. Finally, in section VII conclusions and future works are discussed.

II. Proposed approach

The novel idea is to introduce threshold based scheduling schemes before optimization. Two scheduling schemes based on threshold are introduced. First one is OOBS followed by SBS. The scheduling schemes used to increase the ASE and reduce BER. The quality users from the scheduler are applied as input to the optimizer. In optimizer the subcarrier allocation and power allocation are carried out using PSO and GA.

A. On - Off based scheduling scheme (OOBS)

Users' selection is based on the predefined threshold value. It does not schedule the users that are below the threshold value even when there is space to accommodate more. The average spectral efficiency of OOBS scheduling scheme is given by

$$ASE = K \left[\sum_{n=q}^{N-1} \sum R_n \{\exp(\gamma T_n / \gamma') - \exp(\gamma T_n + 1/\gamma')\} + R_n \exp(\gamma T_n / \gamma')\right] \quad (1)$$

Where K is the total number of users present, γT is SNR threshold, R_n is spectral efficiency for modulation and γ' is the average SNR for all the K users. It is possible to achieve maximum throughput when the feedback load is minimum. AFL is the average number users giving feedback i.e. Channel State Information (CSI) to the base station during guard period. The AFL of OOBS scheduling scheme is given by

$$AFL = \sum_{k=0}^{K} k \binom{K}{k} [1 - p_\gamma(\gamma T)]^k [p_\gamma(\gamma T)]^{K-k} = K[1 - p_\gamma(\gamma T)] \quad (2)$$

B. Switched based scheduling scheme

SBS considers the users above threshold and also the users below threshold, if there is enough space to service them. The users that are below threshold value are arranged in descending order based on their SNR values and serviced based on the availability of the channel capacity. SBS is better than OOBS in terms of better bandwidth utilization. The optimizer is designed to balance the user requirement with the available resources that greatly increases the channel capacity for the incoming users.

The average spectral efficiency (ASE) for SBS scheduling scheme is given by

$$ASE = Ks \sum_{n=1}^{N} R_n \int_{\gamma T_n}^{\gamma T_{n+1}} P_\gamma \, SBS(\gamma) \, d_\gamma \quad (3)$$

Where Ks is the expected number of users, R_n is the spectral efficiency for modulation and P_γ is probability density function. The average feedback load (AFL) for SBS scheduling scheme is given by

$$\begin{aligned} AFL = & \sum_{k=K_s}^{K} k \binom{k-1}{k-K_s} \left[\exp(-\gamma T / \overline{\gamma)}\right]^{K_s} \left[1 - \exp(-\gamma T / \overline{\gamma)}\right]^{k-K_s} \\ & + K \sum_{l=k-K_s+1}^{K} \binom{K}{l} \left[1 - \exp(-\gamma T / \overline{\gamma)}\right]^{l} \left[\exp(-\gamma T / \overline{\gamma)}\right]^{K-l} \end{aligned} \quad (4)$$

III. PROPOSED SYSTEM MODEL

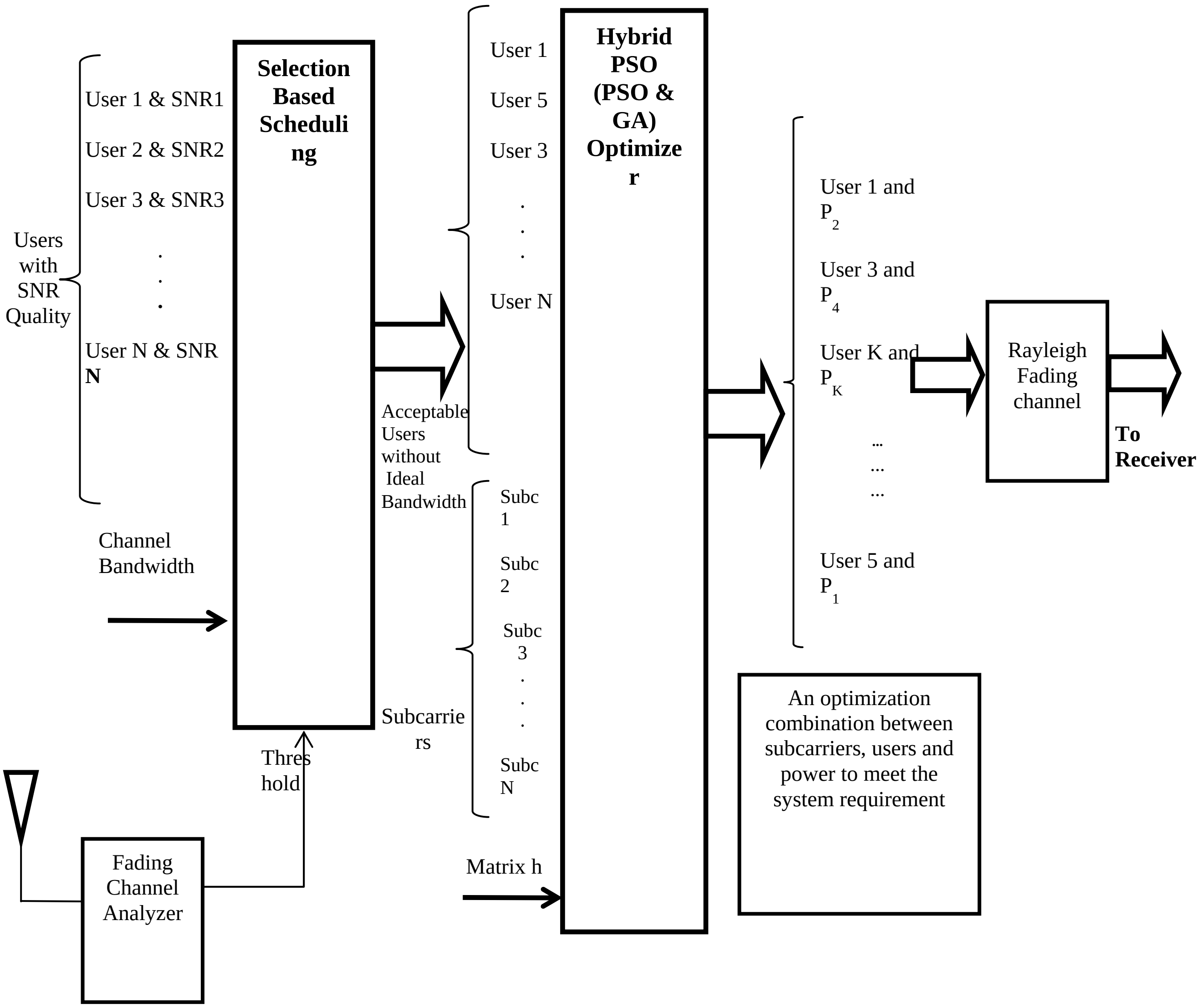

Figure 1: Block diagram of OFDM system resource allocation with scheduling

A Multiuser OFDM system with scheduling is shown in Figure1. The system model consists of the scheduler, PSO (PSO and GA) optimizer, sub channels, Rayleigh fading channel and receiver. The scheduler is fed with different users with SNR values along with channel bandwidth. Based on the scheduling scheme used and threshold values, the acceptable users are decided by the scheduler. The acceptable users along with subcarriers and h matrix are applied to PSO-GA optimizer for effective resource allocation. Channel state information (CSI) is sent to the optimizer. Subcarrier allocation and power optimizations are carried out in PSO-GA optimizer. The system requirements of the three scenarios are different. CSI is known to the BS and the subcarrier and power allocation details are sent to each user through a separate channel. First step is to allocate subcarriers to each user followed by allocation of power. Three different scenarios are considered namely multiuser unicast services, multiuser multicast services at low and constant rate and multiuser multicast services at high rate.

IV. OPTIMIZATION

Optimization of three scenarios

Optimization of the three scenarios is mathematically formulated as follows.

After allocation the capacity of each client is:

$$R_i = \sum \log_2 \left(1 + \frac{P_{i,j} \times \left(h_{i,j} \ H_{i,j} \right)^2}{No \ \times B \times Q^{-1} \left(Pe_{i,j} \right)} \right) \tag{5}$$

Where,

$$Q(x) = 2 / \sqrt{\pi \int_x^\infty e^{t^{2/2}} dt} \tag{6}$$

P_i is the power of client i, h is the matrix mapping users impulse responses to subcarriers, No is the power spectral density of noise, B is the bandwidth, Q^{-1} is the inverse Q function, P_e is bit error rate for each client and H is the matrix showing mapping between each subcarrier and users.

$$H_{i,j} = \begin{cases} 1, \text{ if channel j is occupied by user i} \\ 0, \text{ otherwise} \end{cases}$$

Client Fairness formula is given by

$$F = \frac{\left(\sum_i R_i \right)^2}{\sum_j \left(R_i^2 \right)} \tag{7}$$

Where R_i is the capacity of client. System requirements of the three schemes MCSPF, MPF and MMC are dealt as follows. MCSPF is the multiuser unicast services tends to maximize the total system capacity, MPF is multiuser multicast services at low and constant rate allocate the capacity fairy among users and MMC is multiuser multicast services at high rate increases the lowest user’s capacity.

The system requirement of MCSPF is to maximize the total capacity with the constraints fairness and power is given by

$$\max \left(\sum_i \sum_j \log_2 \left(1 + \frac{P_{i,j} \times \ (h_{i,j} H_{i,j})^2}{N_0 \times B \times Q^{-1} (Pe_{i,j})} \right) \right) \tag{8}$$

The requirement of MPF is to allocate the capacity fairly among users with the constraint total power is given by

$$\max \left(\frac{\left(\sum_i \sum_j \log_2 \left(1 + \frac{P_{i,j} \times \left(h_{i,j} \ H_{i,j} \right)^2}{No \times B \times Q^{-1} \left(Pe_{i,j} \right)} \right) \right)^2}{\sum_i \left(\sum_j \log_2 \left(1 + \frac{P_{i,j} \times \ (h_{i,j} \ H_{i,j})^2}{No \times B \times Q^{-1} (Pe_{i,j})} \right)^2 \right)} \right) \tag{9}$$

System requirement of multiuser multicast services at high rate (MMC) is increase the capacity of the lowest capacity users in all users with the constraint total power is given by

$$\max \left(\min \left(\sum_i \log_2 \left(1 + \frac{P_{i,j} \times \left(h_{i,j} H_{i,j} \right)^2}{N_0 \times \mathrm{B} \times \mathrm{Q}^{-1} \left(P_{ei,j} \right)} \right) \right) \right) \tag{10}$$

The above said system requirements subject to the following constraints.

$$\begin{aligned} &C1 : \sum_{i=1}^{K} \mathrm{H}_{i,j} \ p_{i,j} = P_{total} / N \\ &C2 : p_{i,j} \geq 0 \text{ for all i,j} \\ &C3 : \mathrm{H}_{i,j} = \{0,1\} \text{ for all i,j} \\ &C4 : \sum_{i=1}^{K} H_{i,j} = 1 \text{ for all j} \\ &C5 : BER_i <= BER_i^{\lim} \text{ for all i} \end{aligned} \tag{11}$$

H_{ij} is the subcarrier mapping with respect to users, $P_{i,,j}$ is the power of client and N is the number of available subcarriers in the system. In C1 the power in each subcarrier is allocated equally. In C2 power takes a positive value and it is always greater than zero. In C3 and C4 each subcarrier can only be allocated to one specific user in one allocation. $H_{i,j}$ =1 indicates subcarrier is allocated, else subcarrier not allocated and in C5 BER of each user must be within the specified limits.

V. SCHEDULING AND OPTIMIZATION

A. SBS scheduler

In an OFDM system there are K users and N subcarriers. SBS scheduling screens the best users based on SNR and the optimizer allocates subcarriers and power to users. The overall BER rate of the system depends on the incoming users SNR. The mode of operation of SBS is shown in the Figure2 and its operation is explained below. Base station initially transmits pilot carrier to all the users consecutively in need of CSI. Each user will receive the pilot carrier. All the users have to estimate its SNR value, following the reception of pilot signal from the BS. The estimated SNR value of each user is compared with the predefined threshold value of SNR. CSI of each user is communicated to base station. The steps involved in SBS are as follows. Its operations are explained in Figure 2. The PSO-GA optimizer is described with a flowchart in Figure 3.

Step 1: Based on the threshold value and the user's SNR the acceptable users are found.

Step 2: If the acceptable users are less than the channel capacity, the unacceptable users are arranged in descending order based on their SNR value.

Step 3: The channel is occupied based on the availability.

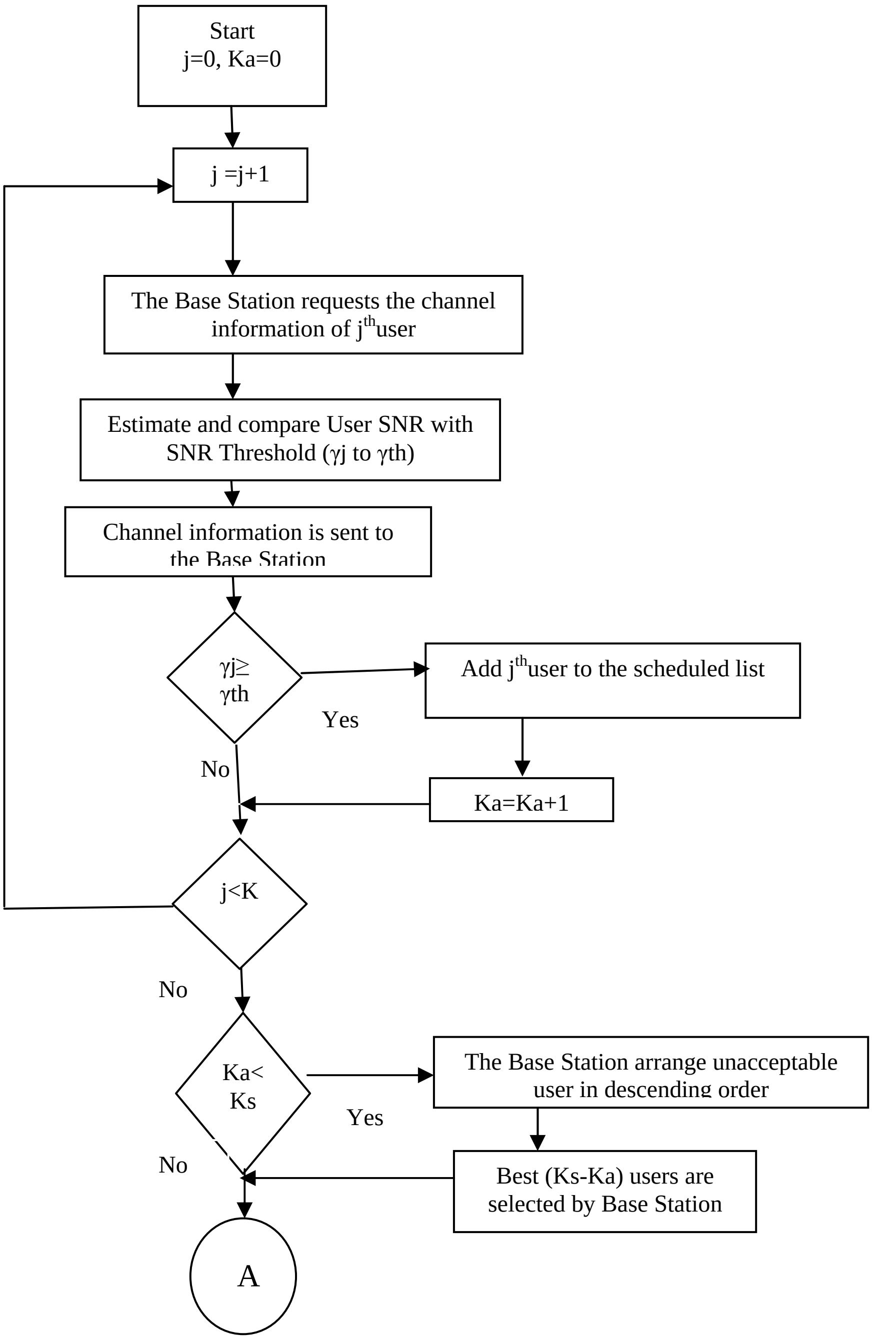

Figure 2. Flowchart of SBS scheduling scheme

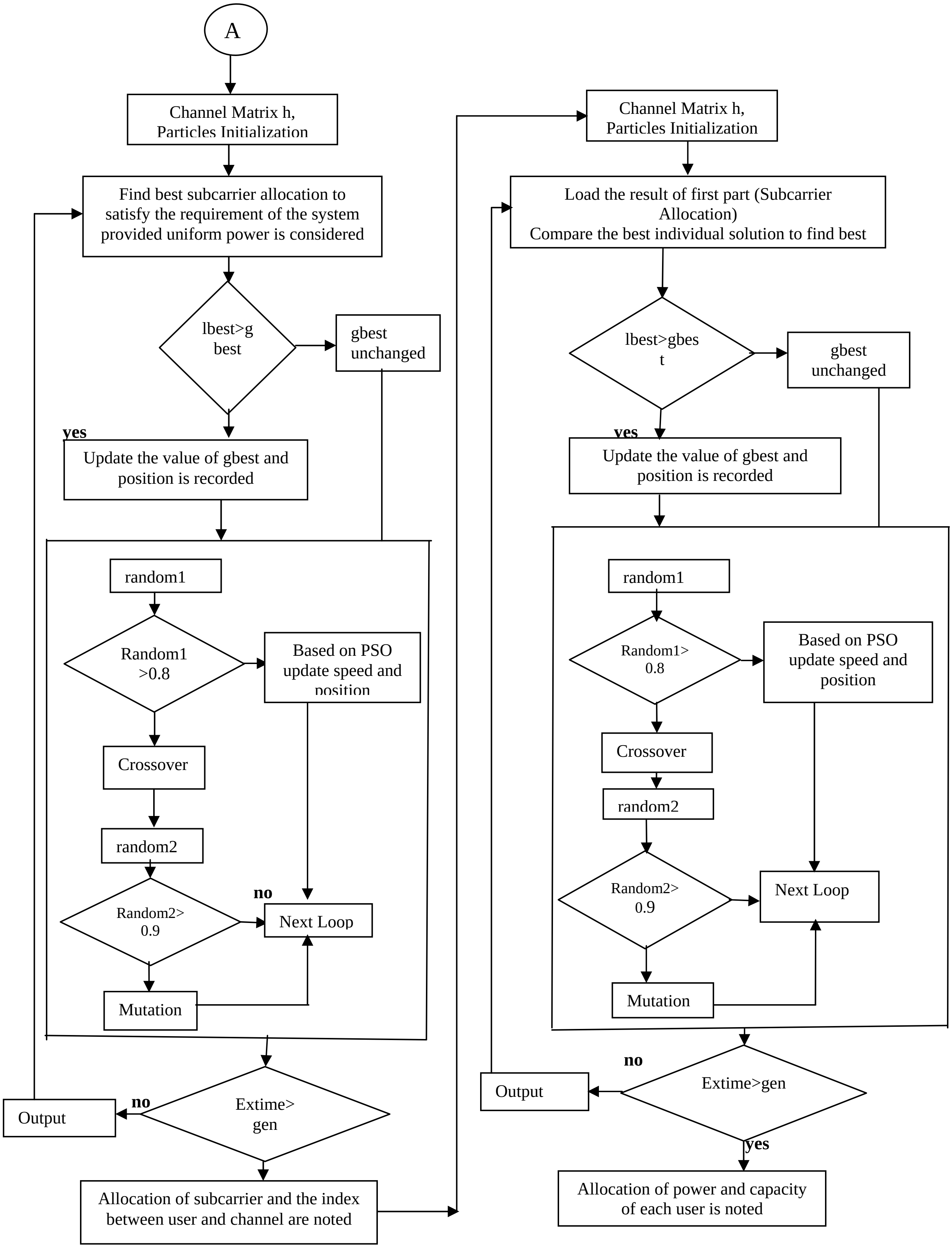

Figure3.Flowchart of PSO-GA optimizer

B. PSO-GA optimizer

The best users based on the scheduling are given as input to PSO optimizer. For subcarrier allocation, channel matrix H must be known. Based on the subcarrier mapping, the power allocation starts for each user. Two values such as gbest and lbest are important in PSO. lbest is the individual best position and gbest is the information derived from global or from their neighbors. Based on the two values the position and velocity are updated. At the beginning stage the particles and channel matrix are initialized. If lbest values are greater than gbest values then lbest is considered as gbest, otherwise the previous gbest value is maintained. Consequently the particles are updated. The power allocation depends on the subcarrier allocation. PSO provides quicker solution and it is having faster convergence rate, but not able reach global optima for subcarrier allocation. To overcome the disadvantage (local optima) of PSO, GA is introduced. In GA, two random numbers are generated between 0-1 and operations like selection, cross over and mutations are handled.

VI. SIMULATION RESULTS

The parameters that are taken for simulation are shown in Table I

Scheduling Schemes	Input Parameters	Subcarrier Allocation	Power Allocation
SBS OOBS	Number of users=20 Channel Bandwidth =1MHz		
	Iterations	100	100
	Generations	100	100
	C1	0.2	0.2
	C2	0.2	0.2
	Cross over	0.1	0.1
	Mutation	0.1	0.1
	Total power	100	100
	Max velocity	1	0.2

TABLE: I SIMULATION PARAMETERS

A. **SBS**

The numbers of users taken are 20 and threshold value is randomly chosen. The users are allocated with random SNR values. The users above threshold out of 20 users are considered. The unacceptable users are arranged in descending order and based on the availability of the channel capacity few more users are considered for scheduling along with acceptable users. Figure 4 shows the comparison of three scenarios MCSPF, MPF and MMC are plotted for the capacity levels of the individual users. The channel capacity of MCSPF is good over the other two. In MCSPF maximum capacity is achieved and in MPF fairness among users is considered. In MMC maximum of minimum user's capacity is dealt.

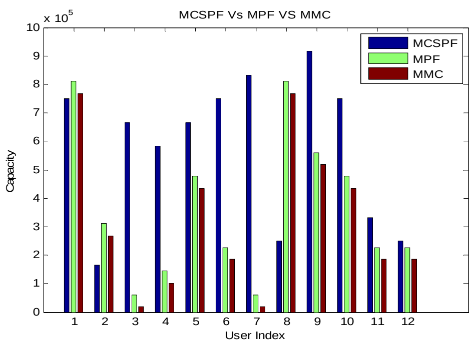

Figure 4 User index vs. Capacity

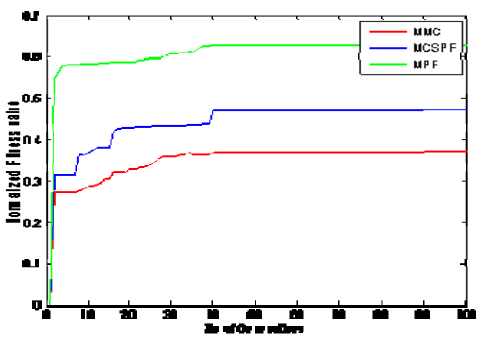

Figure 5: Generations vs. Fitness

Figure 5 deals with generations and fitness relation of three methods. The fitness values for capacity and power for three different scenarios are compared in this plot. The most complicated process is MMC and it takes longer time to converge. The less complicated process is MPF and convergence rate is faster. Figure 4 deals with the maximum capacity allocation of individual users achieved during the 10th generation itself. Modified PSO performs better than normal PSO. The performance of channel capacity allocation in MPSO is better than existing normal PSO. The overall capacity of the proposed system is directly proportional to the number of generations configured. But the increased number of generations leads to delay in execution of the process.

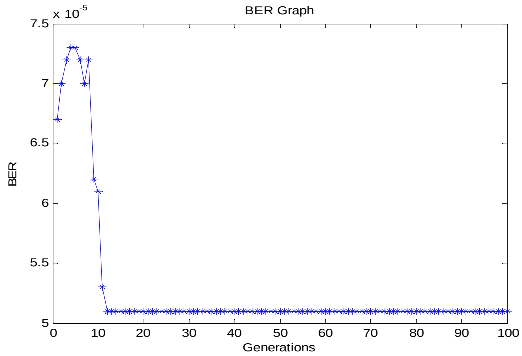

Figure 6: BER vs. Generations of SBS

Figure 6 deals with BER and generations. The BER is fairly reduced up to 5.1 e^{-05}dB due to the allocation of the entire channel even though the Ka < Ks. The initial variation in resource allocation is stabilized in the 15th generation.

B. **OOBS**

In OOBS, even though the channel capacity can accommodate more number of users, only the users above threshold are considered for scheduling. Here the selected channel length greater than acceptable user (Ka < Ks), AFL follows binomial distribution. Figure 7 deals with BER and generations. The BER is comparatively reduced up to 7.2 e^{-05} dB. From the two sets of graph, BER performance is better with SBS scheme.

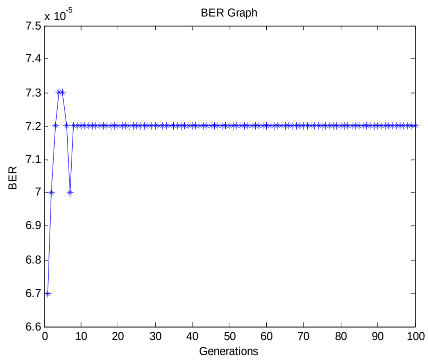

Figure 7: BER vs. Generations of OOBS

VII. Conclusion

The combination of threshold based scheduling mechanism with PSO and GA optimization identifies quality users based on SNR values. Among the two scheduling methods, SBS is better than OOBS in terms of BER. Sub optimal allocation of subcarrier and power allocation is carried out by the optimizer. Three scenarios of OFDM system are optimized using the suggested approach. The PSO and GA optimization outperforms normal PSO in terms of convergence. There is an improvement in ASE and reduction in BER. The performance of the system can be improved by adopting multi objective optimization.

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