

Research Article

Hybrid Genetic Crossover Based Swarm Intelligence Optimization for Efficient Resource Allocation in MIMO OFDM Systems

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Abstract: Rapid development of wireless services, leads to ubiquitous personal connectivity in the world. The demand for multimedia interactivity is higher in the world which leads to the requirement of high data transmission rate. Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) is a future wireless service which is used to overcome the existing service problems such as development of subscriber pool and higher throughput per user. Although it overcomes the problems in existing services, resource allocation becomes one of the major issues in the MIMO-OFDM systems. Resource allocation in MIMO-OFDM is the optimization of subcarrier and power allocation for the user. The overall performance of the system can be improved only with the efficient resource allocation approach. The user data rate is increased by efficient allocation of the subcarrier and power allocation for each user at the base station, which is subject to constraints on total power and bit error rate. In this study, the problem of resource allocation in MIMO-OFDM system is tackled using hybrid artificial bee colony optimization algorithm based on a crossover operation along with Poisson-Jensen in equation. The experimental results show that the proposed methodology is better than the existing techniques.

Keywords: Genetic crossover operator, hybrid artificial bee colony optimization, multiple-input multiple-output, orthogonal frequency division multiplexing, swarm intelligence

INTRODUCTION

Future wireless services called as a Multiple-Input Multiple-Output (MIMO) wireless link which makes use of multiple antennas at both the transmitter and the receiver. The single input single output has random channel where as MIMO channel has minimum number of antennas in both transmitter and receiver end. MIMO channel does not need additional power requirements for data transmission (Munz *et al.*, 2002). In Orthogonal Frequency Division Multiplexing (OFDM), a broadband frequency-selective channel is decoupled into multiple flat fading channels through efficient fast Fourier transform operations. These two technologies are combined which is called MIMO-OFDM (Noor-A-Rahim *et al.*, 2011) for the efficient data transmission and becomes, the stronger candidate for next generation wireless services. With the increase of the technology-savvy population, there is now a huge demand for rich multimedia interactivity. Commercial cellular systems have to cope with not only an increase in the number of users, but also with an increase in the data rate requirement per user.

In order to achieve a higher system performance for multimedia applications in wireless communications, various methods have been proposed in recent years (Kumar and Singh, 2011). The system performance is increased in MIMO system by using multiple antennas in transmitter and the receiver. The MIMO-OFDM system has attracted a lot of researchers due to its efficient way to increase performance of the system capacity. MIMO develops spatial diversity by having several transmit and receive antennas. The system performance is increased by utilizing the parameters of the transmitter and receiver for allocating the power for that parameter (Liejun, 2011). Many algorithms are used for allocation of subcarrier and power to the user or parameters in MIMO-OFDM system. The algorithms such as water filling, particle swarm optimization, genetic algorithm, artificial bee colony algorithms are used for efficient allocation sub carrier and power to the user.

In general the resource allocation problem in MIMO-OFDM has been classified into two categories: Margin Adaptive (MA) and Rate Adaptive (RA) (Kim *et al.*, 2006). Margin-adaptive resource allocation

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scheme is used in Wong *et al.* (1999) for minimizing the total transmission power based on the allocation of user data rates and Bit error rate. The rate adaptive resource allocation method was used in Jang and Lee (2003) for maximizing the total data rates by using power and BER constraints. It was shown that in order to increase the total capacity of the system, each subcarrier is allotted to the user with the best gain on it.

The MA Optimization technique has been dealt with efficiently in (Reddy, 2007). The proportional rate constraint is included in the existing RA optimization problem in (Wong *et al.*, 2004) for efficient resource allocation. However, the introduction of this constraint makes the optimization problem non-linear thus increasing the difficulty in finding the optimal solution because the feasible set is not convex.

Rate and power allocation for the user are considered to be a major issue in MIMO-OFDM system. To simplify the problem, both of them are dealt separately. In this study, swarm intelligence optimization technique is proposed to allocate subcarriers, with the aim to maximize total capacity. The proposed technique is used to generate the subcarrier allocation assuming equal power to all users. After the subcarrier allocation, the power allocation can be performed.

LITERATURE REVIEW

Zhang and Letaief (2005) presented an adaptive resource allocation approach for MIMO-OFDM. The aim of this approach is to allocate the resource efficiently by combining the subcarrier allocation, power and the bit distribution based on the channel instantaneous. This approach includes:

- The power efficiency is enhanced.
- Quality of service requirements, including bit-error rate and data rate is used.
- Ensure fairness to all the active users.
- Be applied to systems with various types of multiuser-detection schemes at the receiver.

The reduced complexity algorithm is developed by the author during the real time implementation of a MIMO-OFDM system. The sub carrier is allocated to the user by splitting joint resource-allocation problem into a single user optimization problem based on the user's spatial separability.

Pan and Aissa (2005), presented a dynamic resource allocation scheme using selective beam forming for MIMO/OFDM systems. The eigenvalue decomposition is applied to the subset of channel correlation matrices for selecting the beam forming from the subset. The power and data rate is allocated based on the channel gain and selected beam forming under the constraint of fixed power and overall bit rate. The SNR of each sub carrier obtained from the previous stage is maximized for efficient resource allocation.

Morris and Athaudage (2006) investigate the problem of resource allocation based on the method called weighted proportional fair for MIMOOFDM system. The resource allocation can be done in the future wireless networks based on the two conditions such as the method used for resource allocation should explore the multi-user diversity and all the user in the system should be treated fairly. The algorithm used in this study is an extension of original proportional fair and the algorithm is used to satisfied user Qos requirements based on bit rate and bit error rate. The performance of the algorithm is evaluated using Monte Carlo method and it shows that the algorithm used in this study is better than the other algorithm in efficient manner.

Ayad *et al.* (2011) presented a new resource allocation algorithm for the future wireless communication systems such as MIMOOFDM. The system consists of multiple transmitter and receiver antennas and Orthogonal Frequency-Division Multiplexing (OFDM). The singular value decomposition is used to split the MIMO channel into sub channel for each subcarrier. The subcarrier is allocated to the user based on the Euclidean distance value of all the gains of spatial sub channel. The Lagrange multiplier is used to allocate the power to the subcarrier and the experimental results shows that the resource allocation using SVD is better than other existing algorithms.

Sharma and Anupama (2011) presented a technique for resource allocation for MIMO OFDM systems with proportional rate constraint. The author used hybrid genetic algorithm based on deterministic algorithm for efficient resource allocation. The bit distribution and power allocation is done efficiently using the water filling algorithm. The hybrid GA giver better results than previous methods for resource allocation even though the number of users for allocation is increased.

Chen and Swindlehurst (2012) presented a technique for allocation problem based on game theory perspective for MIMOOFDM downlink broadcast channel. The spatial block is combined with the multiplex subset along with the time sharing for each user and it is applied to the solution obtained from the game theory. The algorithm used in this study had advantages of low computational complexity. Numerical results and analysis are provided to compare the performance of the different resource allocation methods.

Annauth and Rughooputh (2012) discussed resource allocation for multiuser OFDM system. The authors used Modified particle swarm optimization technique for solving the resource allocation problem.

MATERIALS AND METHODS

Artificial bee colony algorithm: Karaboga (2005) presented a technique based on the behavior of bees called artificial bee colony algorithm for solving the

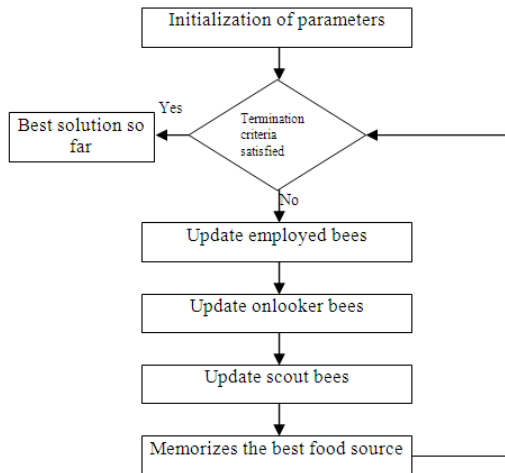


Fig. 1: Phases of artificial bee colony algorithm

optimization problems in efficient manner. The method consists of three major components such as employed, unemployed foragers and food sources. The appropriate food source is explored by employee bees based on its previous knowledge. The unemployed bee searches the food source without any previous knowledge about food source location. The types of unemployed bees are scout bees and onlooker bees. The main work of the scout bees are searching for food around the hives. The best food source is selected based on the waggle dance in the hive and the food sources are selected by onlooker bees. In this scenario, the food sources in ABC are considered as a number of solutions obtained to the optimization problems, the food source location in ABC represents the location or the way solution to the optimization problem and trait of the food source represents the fitness of the solutions.

The location of the food sources are arbitrarily selected by the employee bees at the initial stage and their nectar qualities are measured. The measured nectar quality is shared with the onlooker bee for selecting the best food source for exploration. The employee bees are waiting at the dancing area in the mean time or they select the new food sources from the previously collected information and again shared it with onlooker bee. It is continued until the onlooker bee selects the best food sources from the set of food sources given as input to the bees. The best food sources are selected based on the nectar quality and it is collected by employee bee during the first cyclic phase. The complete process is shown in Fig. 1 as discussed in (Annauth and Rughooopath, 2012).

Crossover operator: The genetic algorithm is used for selecting the best solution to the optimization problems. In order to obtain the best solution, genetic algorithm uses several operators such as crossover operator, mutation operator. Although the genetic algorithm gives better results, it has some disadvantages such as unreliable results in certain situations. In this study, crossover operator from genetic algorithm is combined

with artificial bee colony algorithm for best results. The crossover operator is used to produce new solutions from the existing solutions which are considered as parents. The crossover is applied to the solutions based on the calculation of probability of the existing solution (Karaboga, 2005; Holland, 1962).

Hybrid Crossover Based Artificial Bee Colony (CBABC) algorithm: The proposed ABC with crossover has five different stages.

In first stage, the parameters used for obtaining the best solution is initialized and given as an input. In second stage the employee bee started to collect the information regarding the food sources such as nectar quality. In third stage the existing solution is considered as parents to produce new solution by applying the crossover operator. The crossover stage should maintain balance between the diversification and intensification. Fourth stage is onlooker bee stage where the best solution is selected based on the information shared by employee bee. The information about the food sources are shared by employee bee with onlooker bee is considered as a fitness value of the food sources. The best solution is identified using the fitness value. In last stage the rejected food sources are replaced using the new food sources by scout bee.

The algorithm of Crossover Based Artificial Bee Colony (CbABC) algorithm outlined as follow.

Hybrid Crossover Based Artificial Bee Colony (CbABC) Algorithm.

Initialize all the parameters.

Repeat while Termination criteria is not meet:

- Step 1:** Employed bee phase for computing new food sources.
- Step 2:** Crossover phase to increase the quality of solution.
- Step 3:** Onlooker bees phase for updating the location of food sources based on their nectar amounts.
- Step 4:** Scout bee phase for searching new food sources in place of rejected food sources.
- Step 5:** Memorize the best food source identified so far.

End of while loop.

Output: Best solution identified so far.

The input parameters are initialized and evaluated in the first stage. The information related to the population is collected by employee bee in the second stage. The crossover probability is calculated for the input population and if the criteria meet then the crossover operator is applied in the third stage for obtaining new solution. The worst solution is replaced by new solution obtained from the crossover operation. The process is repeated until the best solution is found by onlooker bee. The diagrammatic representation of the modified artificial bee colony algorithm is shown in the Fig. 2.

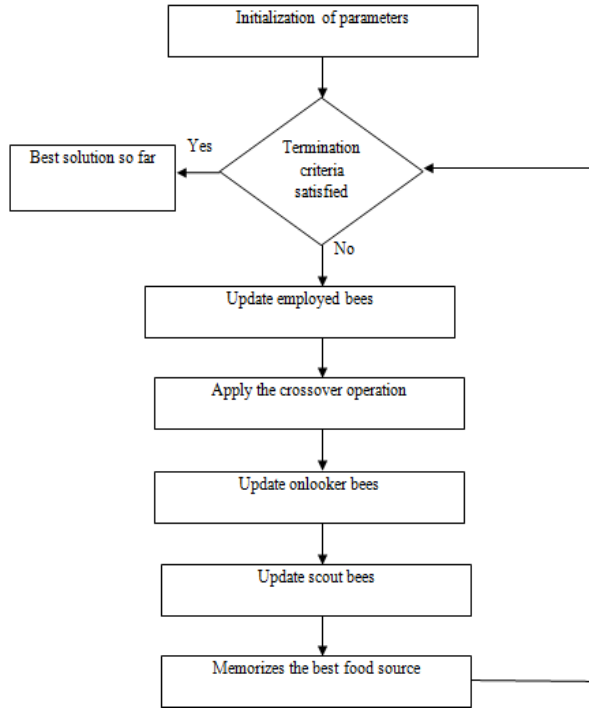


Fig. 2: Phases in hybrid Crossover based Artificial Bee Colony (CbABC) algorithm

Proposed architecture: In proposed architecture of MIMO-OFDM system, K users and N subcarriers are considered as an input to the system. The channel state information is assumed as known factor in the receiver and transmitter. The channel changes little during the transmission (Talbi, 2009). The user experiences during the transmission of data in MIMO-OFDM system are assumed to be independent fading. The channel gain is denoted as $g_{k,n}$ where k is the user, n is the subcarrier. The additive white Gaussian noise is considered as $s^2 = N_0 \frac{B}{N}$ where N_0 is the noise spectral power density. The SNR ratio for subchannel is denoted as $h_{k,n} = \frac{g_{k,n}}{s^2}$ and Kth user's received SNR on subcarrier h is $\gamma_{k,n} = p_{k,n} h_{k,n}$. In proposed architecture uses hybrid artificial bee colony based on crossover operator and it considered the subcarrier and power allocation as an optimization problem in this study. This problem is efficiently solved and both subcarrier and power are allocated to the user efficiently. Before proceeding to the allocation process the optimization problem is considered to be simplified using the following steps. The SNR ratio and transmit power is varied based on the calculation of Bit Error Rate (BER). The received power is calculated using the $r_{k,n}$ bits per symbol in M level of QAM with square signal:

$$f_k(r_{k,n}) = \frac{N_0}{3} \left[Q^{-1} \left(\frac{p_e}{4} \right) \right]^2 (2^{r_{k,n}} - 1)$$

The MQAM with gray bit mapping is considered as well as SNR $\gamma_{k,n}$, number of bits is $r_{k,n}$ subjected to approximation of 1 dB for $r_{k,n} \geq 4$ and $BER \leq 10^{-3}$ are considered as parameters during the calculation of BER. The BER is calculated as follows:

$$BER_{MQAM}(\gamma_{k,n}) \approx 0.2 \exp \left[\frac{-1.6\gamma_{k,n}}{2^{r_{k,n}} - 1} \right] \quad (1)$$

Where as $r_{k,n}$ is calculated as follows:

$$r_{k,n} = \log_2 \left(1 + \frac{\gamma_{k,n}}{\Gamma} \right) = \log_2 \left(1 + p_{k,n} H_{k,n} \right) \quad (2)$$

Where $\Gamma \approx -\ln(5BER)/1.6$ constant SNR is gap, and $H_{k,n} \approx h_{k,n}/\Gamma$ is the effective sub channel SNR.

The optimization problems for simple OFDM systems is:

$$\max_{c_{k,n}, p_{k,n}} \sum_{k=1}^K \sum_{n=1}^N \frac{c_{k,n}}{N} \log_2 \left(1 + \frac{p_{k,n} H_{k,n}}{N_0 B/N} \right) \quad (3)$$

Subject to,

$$C1: c_{k,n} \in \{0,1\} \forall k, n$$

$$C2: p_{k,n} \geq 0 \forall k, n$$

$$C3: \sum_{k=1}^K c_{k,n} = 1 \forall n$$

$$C4: \sum_{k=1}^K \sum_{n=1}^N c_{k,n} p_{k,n} \leq P_{tot} \quad (4)$$

Where $c_{k,n}$ is represented as subcarrier allocation indicator and P_{tot} is the represented as total transmit power constraint. If $c_{k,n} = 1$ then the subcarrier n is allocated to the user k. The aforementioned formulation for simple OFDM system is extended to MIMO-OFDM with same assumption such as user experiences, channel state information etc. The N_T and N_R antennas are considered as transmitter and receiver and it can be formulated into $N_T \times N_R$ channel matrix such as:

$$H_{k,n} = \begin{pmatrix} h_{11} & \cdots & h_{1N_T} \\ \vdots & \ddots & \vdots \\ h_{N_R1} & \cdots & h_{N_R N_T} \end{pmatrix} \quad (5)$$

For the MIMO-OFDMA system, the optimization problem can be formulated as:

$$\max_{c_{k,n}, p_{k,n}} \sum_{k=1}^K \sum_{n=1}^N \frac{c_{k,n}}{N} \log_2 \left[\det \left(I_{N_R} + \frac{p_{k,n} H_{k,n} H_{k,n}^H}{N_0 B/N} \right) \right] \quad (6)$$

where, $M = \min(N_T, N_R)$ $\lambda_{k,n,i}$ is the i th eigen-value of matrix $H_{k,n}, H_{k,n}^H$. According to Poisson-Jensen in-equation:

$$\sum_{i=1}^M \log_2 \left[1 + \frac{z_0 - p_{k,n}}{1 - p_{k,n} z_0} \lambda_{k,n,i} \right] \leq M \log_2 \left[1 + \frac{z_0 - p_{k,n}}{1 - p_{k,n} z_0} \lambda_{k,n,i} \right] \approx M \log_2 \left[1 + \frac{z_0 - p_{k,n}}{1 - p_{k,n} z_0} \lambda_{k,n,i} \right] \quad (7)$$

Where $z_0 = N_0 B/N$ and the value of $N_0 B/N < 1$. The channel condition of user k is considered as Frobenius-norm of $H_{k,n}$. If the SNR is high enough, then left side of in-equation can be rewritten as:

$$\sum_{i=1}^M \log_2 \left[1 + \frac{z_0 - p_{k,n}}{1 - p_{k,n} z_0} \lambda_{k,n,i} \right] \approx \log_2 \left[\prod_{i=1}^M \left(1 + \frac{z_0 - p_{k,n}}{1 - p_{k,n} z_0} \lambda_{k,n,i} \right) \right] = \log_2 \left[\left(\frac{z_0 - p_{k,n}}{1 - p_{k,n} z_0} \right)^M \det(H_{k,n} H_{k,n}^H) \right] \quad (8)$$

The simplified optimization problem is:

$$\sum_{k=1}^K \sum_{n=1}^N \frac{c_{k,n}}{N} M \log_2 \left[1 + \frac{z_0 - p_{k,n}}{1 - p_{k,n} z_0} \lambda_{k,n,i} \right] \quad (9)$$

Proposed algorithm for resource allocation:

Input: Input channel gain matrix, number of users, number of subcarrier or channels.

Output: Sub channel allocation and power allocation for the user.

1. Initialize the populations of bees as number of channels
2. Evaluate the channels
3. Cycle = 1
4. Repeat
5. Calculate the capacities of each and every channel present in the input and assume the capacities as a fitness function:

$$\sum_{k=1}^K \sum_{n=1}^N \frac{c_{k,n}}{N} M \log_2 \left[1 + \frac{z_0 - p_{k,n}}{1 - p_{k,n} z_0} \frac{1}{M} \text{tr}(H_{k,n} H_{k,n}^H) \right]$$

6. Calculate the probability values for each channel based fitness function
7. Sort out the channel based on the probability levels R_i
8. In onlooker bee phase
9. Select the first n subcarriers based on the probability values

10. Crossover operation
11. For ($j = 1$ to n) do
12. Select channels based on the highest probability
13. Select the two points randomly from the selected parents for crossover
14. Generate two new offsprings by swapping the parents from the starting to first random point and from second random point to end of the parent
15. The fitness value is calculated for new offsprings obtained from previous steps
16. Calculate the probability value R_i for the new offsprings v_i using their fitness value
17. Apply the greedy selection process x_i and v_i and replace the new solution with existing solution
18. Allocate the best channel so far to the existing user
19. Power is calculated for the allocated channel to the user using the formula:

$$p_{k,n} = \frac{P_{tot} + \sum_{i=1}^n \frac{1}{H_i}}{\sum \text{fitness}} - \frac{1}{H_i}$$

20. Cycle = cycle+1
21. Until cycle = Maximum Cycle Number (MCN)
22. Scan the users history for checking allocated channels and store it in a variable α
23. If $\alpha > S$ then the additional channels are allocated to the users with less number of channels based on the channel gain

EXPERIMENTAL RESULTS

The channel is assumed to be Rayleigh Channel with four multi-paths in experimental results. The proposed system consist of 128 subcarriers, total bandwidth is 1 Mhz , number of transmitter antennas N_T and receiver antennas N_R present in the proposed system is 4 and the number of users considered here is 500. Gaussian white noise variance N_0 is 0.5 and BER is 10^{-3} . It is assumed that all users require the same service such as File Transfer Protocol (FTP) service. The number of subcarriers allocated to the each user is fixed as 16 in order to obtain high throughput. Simulation parameters are described in Table 1.

The proposed resource allocation algorithm is compared with existing algorithms such as genetic algorithm, Particle swarm optimization and Non dominated Sorting Genetic Algorithm. The proposed algorithm, GA, NSGA and PSO have the same optimization problem aim. In existing algorithm proportional rate constraints along with fairness is

Table 1: Simulation parameters

Parameter	Values
Total bandwidth, B	1 MHZ
Modulation	QAM
Number of sub-carriers (N)	128
Number of transmitter antennas (N_t)	4
Number of receiver antennas (N_r)	4
Number of users (K)	500
Fast fourier transform size	1024

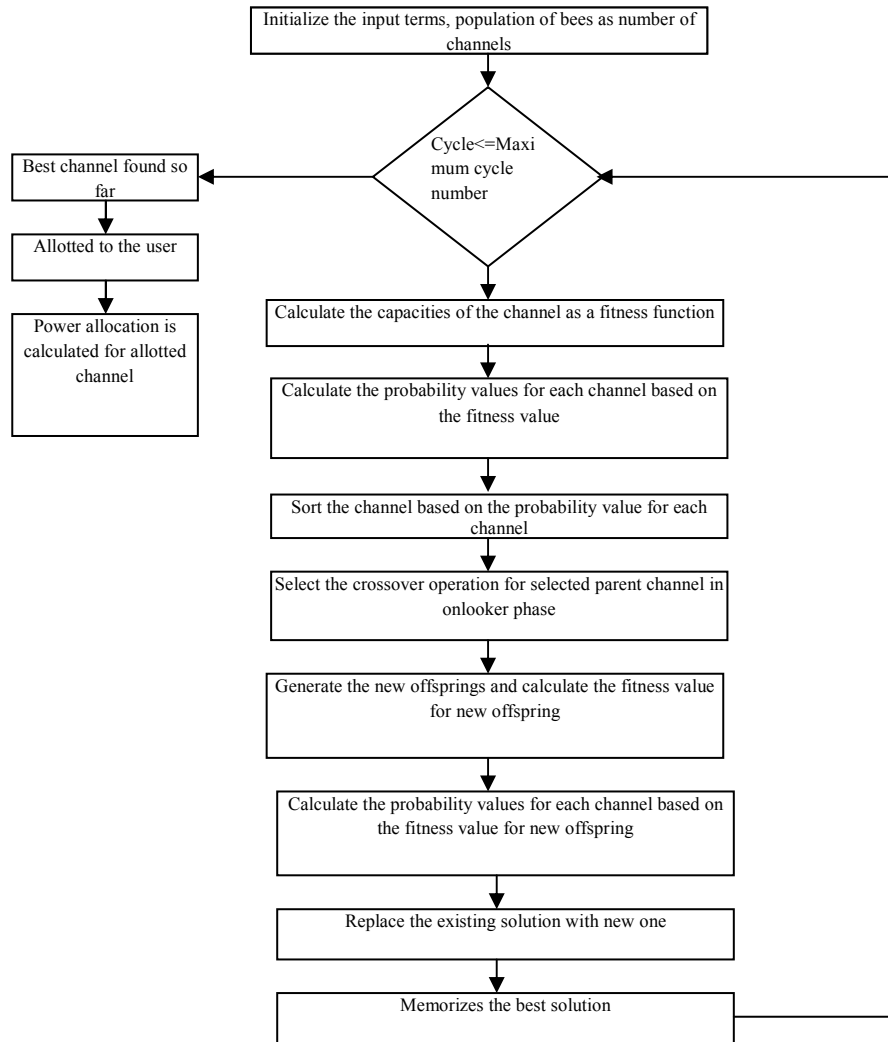


Fig. 3: Working process of the proposed algorithm

introduced for obtaining better allocation. Although it gives good results, it will be complicated during the real time implementation. In order to obtain higher throughput the existing algorithm uses high SNR value. These are the main problems in the existing algorithm and it can be proved in the experimental results. The metrics used to analyze the performance of the existing algorithms and proposed algorithm in the experimental results are SNR, BER and throughput (Fig. 3).

Figure 4 shows that graphical representation of performance of the proposed algorithm with existing algorithm such as GA, NSGA and PSO. The throughput of the proposed algorithm is better than the existing algorithm despite of the SNR value is increased.

Figure 5 shows that graphical representation of performance of SNR value of the proposed algorithm with existing algorithm such as GA, NSGA and PSO. The SNR value of the proposed algorithm is better than the existing algorithm.

Figure 6 and 7 shows that graphical representation of performance of BER value of the proposed algorithm

with existing algorithm such as GA, NSGA and PSO. The BER value of the proposed algorithm is lesser than the existing algorithm.

CONCLUSION

This study presents a low complexity swarm intelligence optimization based algorithm for subcarrier and power allocation for users in MIMO-OFDM system. The proposed system allocates subcarrier and power resources for users using the hybrid swarm intelligence based optimization algorithm. The optimization problem of MIMO-OFDM is considered and is then simplified using Poisson-Jensen equation method. The hybrid artificial bee colony optimization algorithm based on the genetic crossover operator is used for efficient subcarrier and power allocation to the user. The power is calculated for best subcarrier selected in the HCABC algorithm then it is allocated to the user. The simulation results are carried out using the parameters and it shows that the proposed algorithm is

better than existing algorithms such as GA, NSGA and PSO. The proposed algorithm reduces total transmit power and also it satisfies the QoS requirements.

Moreover, the proposed algorithm allocates the subcarriers rapidly than the previous algorithms even though large number of users present in the system.

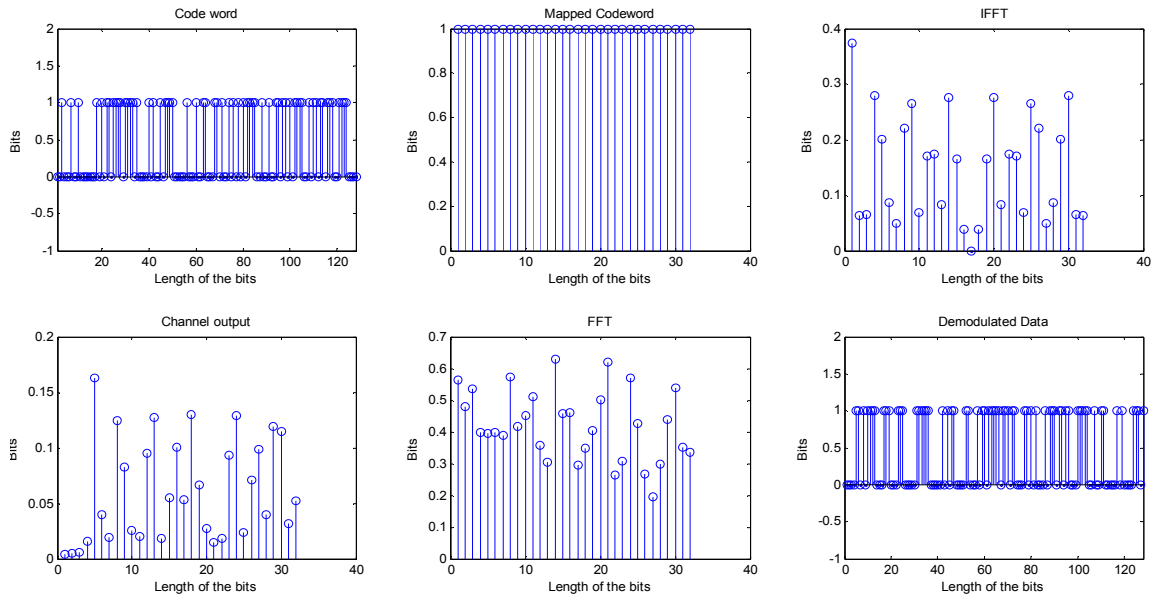


Fig. 4: Plots of QAM

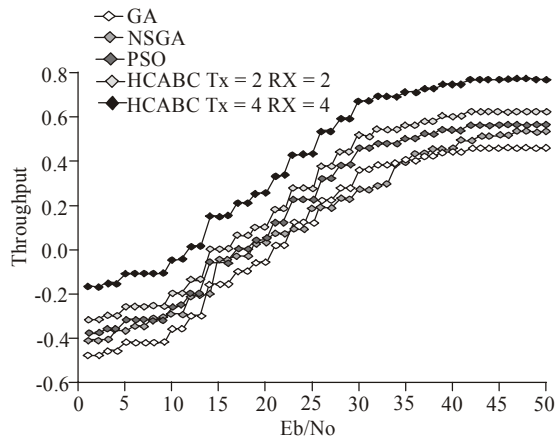


Fig. 5: Throughput vs. SNR

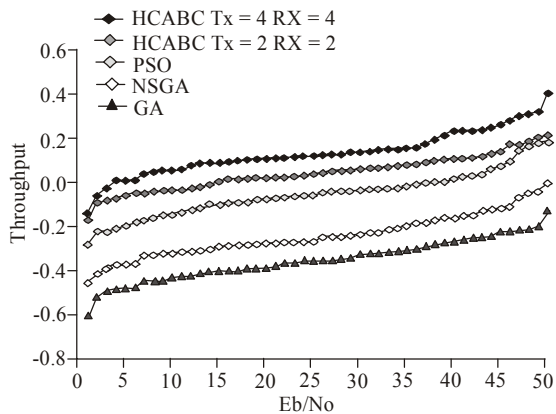


Fig. 6: Performance of SNR

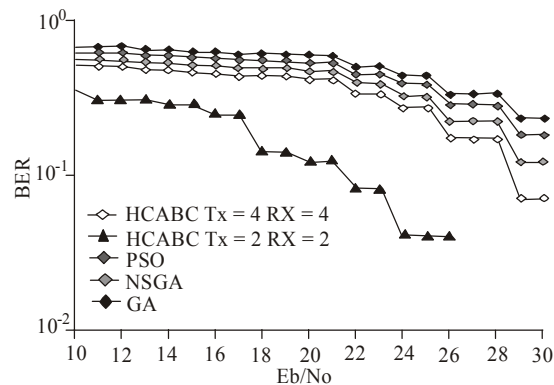


Fig. 7: Performance of BER

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