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# An Efficient Channel Assignment Strategy In Cellular Mobile Network using Hybrid Genetic Algorithm

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**ABSTRACT: A new efficient channel assignment strategy is proposed for allocation of frequency to users appearing in a mobile cellular network. The incoming calls are first allocated channel through the Fixed Channel Allocation (FCA) scheme and if the channels in FCA set are exhausted the channels are allocated using Dynamic Channel Allocation (DCA) scheme. The DCA strategy uses the algorihtm which is a combination of Genetic Algorithm and Simulated Annealing. While Genetic Algorithm provides an optimized solution for this NP hard problem, the simulated annealing is applied as a local search strategy to improve the quality of the solution. The overall blocking probability is reduces as seen from the results.**

**Keywords*:*** Cellular Networks, hybrid channel allocation, channels, blocking, Genetic Algorithm, Simulated Annealing

## I. INTRODUCTION

With the development of the cellular mobile technology in the 1960s at the Bell Labs, mobile communications has become a promising field of expanse serving wider populations. With the exponential increase in the number of users, assigning frequencies to them with good quality was a major challenge. To solve this problem, the concept of cellular communication was initiated. The cellular communication uses a small area called cell. Each cell consists of a hexagonal area with a base station at the center of the cell which forms a link for communication between the users. To satisfy the large demand of mobile telephone services, the frequency channels are needed to be assigned and reused to minimize the interference. This concept is referred to as the Channel Assignment Problem (CAP)[1]. Genetic algorithm (GA) was invented by John Holland in the 1960s. In comparison with evolution strategies and programming, Holland's goal was not only to design algorithms to solve certain complicated problems, but to formally study the phenomenon of adaptation when it occurs in nature and to develop ways using which the mechanisms of natural adaptation could be imported into computer systems.HGA is a combination of Genetic Algorithm and Simulated Annealing and is a new method of distributing the channels to a cellular network since it utilizes the process of natural selection followed by local search method . This new scheme for channel allocation is developed and implemented as opposed to the log domain presented by Smith et. al.[2][3]. The performance of these schemes is analyzed by comparing the blocking probability for different representative ratios involving different schemes of user distribution. Simulated annealing (SA) is a generic probabilistic metaheuristic for the global optimization problem of locating a good approximation to the global optimum of a given function in a large search space. It is often used when the search space is discrete (e.g., all tours that visit a given set of cities). For certain problems, simulated annealing may be more efficient than exhaustive enumeration — provided that the goal is merely to find an acceptably good solution in a fixed amount of time, rather than the best possible solution.

Simulated annealing is a branch of iterative improvement algorithms in which the basic idea is to start with an initial configuration (solution) and make modifications to improve its quality. It starts with a set of configurations. A cost function is used to determine the cost for each configuration.

To search for better solutions (in our case, the lower cost the better), a neighborhood structure is defined on this set of configurations. This neighborhood and the tendency to accept worse moves is the most important factors which led to its usefulness in mobile cellular networks.

Frequency reuse concept comprises of using the same frequency channel simultaneously with other cells subject to the base transceiver station (BTS) distance. However this technique would lead to EMC interferences. Hence an efficient frequency reuse pattern is necessary to minimize the interferences. There are numbers of heuristics approaches being suggested to overcome the channel assignment problems based on fixed reuse distance concept such as neural networks (NNs) in [1], simulated annealing (SA) in [2], and genetic algorithm (GA)[9][10]. The evolutionary algorithm (EA) approaches such as GA outperforms other methods such as NNs, SA and TS, in terms of the ability to explore information over search spaces [6]. This type of algorithm can be used to solve complicated optimization task, such as optimal-local, multi-constrained and NP-complete problems [11].

## II. LITERATURE SURVEY

In [4] by Y. Zhenhua, a modified immune genetic algorithm to solve the problem of channel assignment in cellular radio networks is presented. Three constraints were considered for the channel assignment: the co-channel constraint, the adjacent constraint and the cosite constraint. The objective is to obtain a conflict-free channel assignment scheme among the cells, which satisfies both the electromagnetic compatibility (EMC) constraints and traffic demand requirements. The minimum-separation encoding scheme was introduced to meet the co-site constraint. The genetic operators(crossover and mutation) was proposed to ensure the traffic demand throughout the iterative process. In order to increase the efficiency and velocity of convergence, immune operators are given, such as immune clone, vaccination, immune selection etc. To void local optima, the elite strategy was used. Some well-known benchmark problems were simulated. The significant results indicate that the proposed algorithm is a better approach for solving the channel assignment problem.

Evolutionary algorithms can be applied to a variety of constrained network communication problems with centric type models. The paper [5] by Kleeman *et. al.* shows that with real-world complex network communication problems of this type, sophisticated statistical search is required. This situation occurs due to the fact that these optimization problems are at least NP-complete. In order to appreciate the formal modeling of realistic communication networks, historical network design problems (NDPs) are presented and evolved into more complex real-world models with associated deterministic and stochastic solution approaches discussed. This discussion leads into the design of an innovative multi-objective evolutionary algorithm (MOEA) to solve a very complex network design problem variation called the multi commodity capacitated network design problem (MCNDP).

Y.S. Chia in [13] Adaptive HCA using Simple Genetic Algorithm: A Genetic Algorithm based optimization in HCA scheme is proposed which is capable to adapt the population size to the number of eligible channels for a particular cell upon new call arrivals in order to achieve faster convergence speed. Besides, the proposed approach can handle both the reassignment of existing calls as well as the allocation of channel to a new call in an adaptive process to maximize the utility of the limited frequency spectrum. The simulation for both uniform and non uniform traffic distributions on a 49-cells network model is shown.

D K Singh in [22] A Dynamic Channel Assignment using Modified Genetic Algorithm- The objective of the Dynamic Channel Assignment problem considered here is to assign a required number of channels to each cell in a way to achieve both efficient frequency spectrum utilization and minimization of interference effects (by satisfying a number of channel reuse constraints). Dynamic Channel Assignment (DCA) assigns the channels to the cells dynamically according to traffic demand, and hence, can provide higher capacity (or lower call blocking probability), fidelity and quality of service than the fixed assignment schemes. Devising a DCA, that is practical, efficient, and which can generate high quality allocations, is challenging and is studied in this paper.

## III. HYBRID GENETIC ALGORITHM SIMULATED ANNEALING

The genetic algorithms are a class of evolutionary algortihms that mimic the process of natural selection of biological nature of living organisms. When applied to NP hard problems it has following steps.

(i) INITIAL POPULATION-The algorithm starts by randomly generating an initial population of possible solutions. For our problem, the population is the randomly generated cells. We can select a cell, say cell one and if this cell requires a channel, we start from channel one to last and search for the best to allocate.

(ii) EVALUATION PHASE-The quality measure to decide how fit one individual is among the whole generation is called the fitness. In our application, we can compare the frequency reuse distance and SNR of all the cells created in initial population. The fitness function is the value of both distance and SNR to maintain least interference between co channel cells.

(iii) SELECTION PHASE-The chromosome with better fitness will be selected, and the others will be eliminated. This will help improve the total fitness of the population. After this we sort the other cells that satisfy the condition of allocation of channel one, on the basis of highest SNR.

(iv) CROSSOVER PHASE-After the selection step, the eliminated individuals are added by applying crossover to the selected individual. The selected cells can be used to create another cells having better fitness criterion.

(v) MUTATION PHASE-The mutation process is carried out by changing a random bit of the new genes. These new genes (cells) now become the next candidate to be assigned with channel one but only if they satisfy the fitness criterion.

The Simulated annealing is a local search algorithm. It is based on the analogy between the process of finding a possible best solution of a combinatorial optimization problem and the annealing process of a solid to its minimum energy state in statistical physics. The searching process starts with one initial random solution. A neighborhood of this solution is generated using any neighborhood move rule and then the cost between neighborhood solution and current solution can be found with Equation,

$$C_{diff} = Ci - Ci\_1$$

where $C_{diff}$ represents change amount between costs of the two solutions. Ci and Ci_1 represents neighborhood solution and current solution, respectively. If the cost decreases, the current solution is replaced by the generated neighborhood solution. Otherwise the current solution is replaced by the generated neighborhood solution by a specific possibility calculated in the next equation or a new neighborhood solution is regenerated and steps are repeated until this step.

Unlike other search and optimization techniques, a genetic algorithm promises convergence but not optimality, not even that it will find local maxima. This implies that the choice of when to stop the genetic algorithm is not well-defined. We stop the genetic algorithm process when 50 generations have gone by with no better chromosome identified. Since there is no guarantee of optimality, successive runs of the GA will provide different chromosomes with varying fitness measures. This is one of the drawbacks of using a genetic algorithm for optimization - since there is no guarantee of optimality, there is always the chance that there is a better chromosome lurking somewhere in the search space. GAs are not good at identifying the optimal value of a chromosome for a problem but do very well in identifying the regions where those optima lie. Therefore, we use a hybrid GA every m generations, we anneal the best m% of the population. This has the effect of moving the top chromosomes in that generation (which are the result of exponential convergence toward the best regions) to the local maximum in their region. combined the strengths of genetic algorithm (GA) and simulated Annealing (SA), to solve this problem. These two algorithms are both naturally motivated, general purpose optimization procedures of generating new points in the search space by applying perturbation operators to current points [6]. The difference is that genetic algorithm operates on the whole population and the search process may be trapped in local optima, while simulated annealing possesses the capability of jumping out of local optimization. By reasonably combining the respective advantages of the two paradigms, we develop a hybrid genetic algorithm simulated annealing. Hence, we can combine two algorithms, which is a relatively newer area of research. The GA is carried out as a main frame of this hybrid algorithm while SA is used as a local search strategy to help GA jump out of local optima.

## IV. PROPOSED MODEL

A matrix of 64x64 is created to find the distance between the cells but for convenience we have shown only a 10x10 matrix for the distance. The aim is provide wireless service in providing reusable frequency channels to the available users in a particular area.. We have 70 total frequency bands that needs to be allocated to the users appearing in these 64 cells. We have to therefore allot optimum channels to the area as per the user requirements. The scheme of channel assignment is hybrid channel allocation which is a combination of fixed channel allocation (FCA) and dynamic channel allocation (DCA). The radius of each cell is assumed 1 unit and therefore the frequency reuse distance is calculated for K=3, K=7.

We have assumed radius equal to 1 unit. If the frequency reuse factor or the cluster size is K=3, which implies that the frequency reuse distance is 3 units .We have divided the total 70 channels into two subsets each of FCA and DCA. FCA set has 21 channels while DCA set has 49 channels corresponding to a representative ratio of 21:49.

PSEUDOCODE OF HGA APPLIED TO HCA

Create a hypothetical network of 64 cells.

For all cells

1. Initialize a loop for all the cells that seek channels for user arriving in them.

Assign channel using FCA, ELSE call HGA-HCA

2. HGA

(i) Initialize target population
(ii) Initialize fitness function
(iii) Evaluate the required signal to noise ratio
(iv) For each channel Evaluate the cost of j for each input
    If cost > fitness function
    Sort all X and select the best 4 values of X for mating
(v) Apply crossover operation and mutation.
(vi) Apply mutation operation such that
3. a) Determine an annealing schedule T(i)
    b) Use result of step 4 (ix) as input to the simulated annealing algorithm as X’
    c) WhileT(i)>Tmin
 i) Generate a new solution X’’ which is a neighbor of X’
ii) Compute ΔE= [ fitness X’ – fitness X’’ ]

  iii) If ΔE<0,then always accept the move from X’ to X’’, else accept the move with probability P
  iv) T(i)=T(i)*a
    end while
4. Assign channels to the cells
5. Go to step 3 for the next cell.
6. End for loop.
7. Calculate the Blocking probability

## V. SIMULATION RESULTS

Distance Between each cell is calculated and the matrix of distance between cells is formed. The distance vectors are calculated in the matlab and the result is displayed for distance between each of the 64 cells with the distance of other 64 cells.

A matrix of 64x64 is created to find the distance between the cells but for convenience we have shown only a 10x10 matrix for the distance. While evaluation of fitness function distance, we refer to the distance matrix as shown below.

The simulations are done by using MATLAB. The performance of the proposed HGA based algorithm for the HCA scheme is evaluated in terms of the blocking probability for the incoming calls. The call blocking probability is calculated by the ratio of the total number of new call blocked and the total number of call arrived in the cellular network system. An example of a valid assignment of channels which fulfills the EMC constraints for the 21:49 representative ratio of the HCA scheme is shown in fig.2. This simulation result is optimized by HGA and run under uniform call traffic distribution using Table 1 and 2 as the initial rate. Figure 2 shows the call blocking probability result under nonuniform call traffic distribution. On the other hand, Figure 2 also shows the call blocking probability performance under uniform traffic distribution with average 15 calls per minute as the initial traffic rate shown by table 2. In the simulation results, the percentage increase of traffic load implies that the traffic rates for each of the cell increased by a percentage with respect to the initial traffic rates. The increase is ranging from a percentage of 0 to 60, with respect to the initial traffic rates. According to Figure 2 under nonuniform traffic distribution, the lowest call blocking probability is obtained by the 21:49 HGA-HCA scheme compared with the other HCA scheme with simple GA optimization.

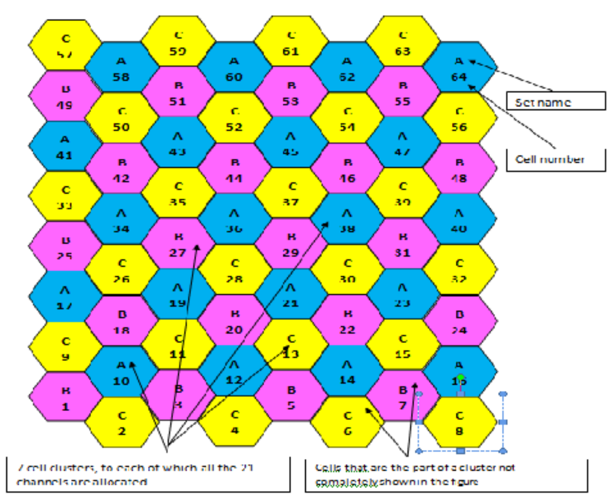


**Fig.1.** Distribution of sets to cells for cluster size 3.

**Table 1: Uniform traffic distribution pattern corresponding to initial users as in [13].**

| *y*-coordinate | *x*-coordinate | | | | | | |
|---|---|---|---|---|---|---|---|
| | ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***6*** | ***7*** |
| 1 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| 2 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| 3 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| 4 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| 5 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| 6 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| 7 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |

**Table 2: Non Uniform traffic distribution pattern corresponding to initial users as in [13].**

| *y*-coordinate | *x*-coordinate | | | | | | |
|---|---|---|---|---|---|---|---|
| | ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***6*** | ***7*** |
| 1 | 60 | 20 | 15 | 30 | 15 | 60 | 30 |
| 2 | 60 | 30 | 15 | 30 | 20 | 20 | 60 |
| 3 | 15 | 30 | 20 | 60 | 60 | 30 | 20 |
| 4 | 60 | 15 | 20 | 30 | 20 | 30 | 60 |
| 5 | 20 | 60 | 15 | 60 | 20 | 30 | 20 |
| 6 | 30 | 20 | 20 | 60 | 30 | 30 | 60 |
| 7 | 60 | 60 | 15 | 60 | 15 | 20 | 30 |

**Table 3 : Tabular representation of results compared with [13].**

| **% Increase in traffic load** | **GA HCA (uniform traffic)** | **GA HCA (non uniform traffic)** | **HGA HCA (uniform traffic) (K = 7)** | **HGA HCA (non uniform traffic) (K = 7)** | **HGA HCA (uniform traffic) (K = 3)** | **HGA HCA (non uniform traffic) (K = 3)** |
|---|---|---|---|---|---|---|
| 0 | 0.23 | 0.16 | .1 | 0.13 | 0.01 | .10 |
| 10 | 0.31 | 0.23 | .15 | 0.21 | 0.03 | .20 |
| 20 | 0.39 | 0.33 | .19 | 0.31 | 0.06 | .28 |
| 30 | 0.48 | 0.4 | .24 | 0.46 | 0.1 | .42 |
| 40 | 0.55 | 0.49 | .26 | 0.53 | 0.13 | .48 |
| 50 | 0.65 | 0.57 | .29 | 0.57 | 0.18 | .50 |
| 60 | 0.75 | 0.75 | .33 | 0.59 | 0.2 | .52 |

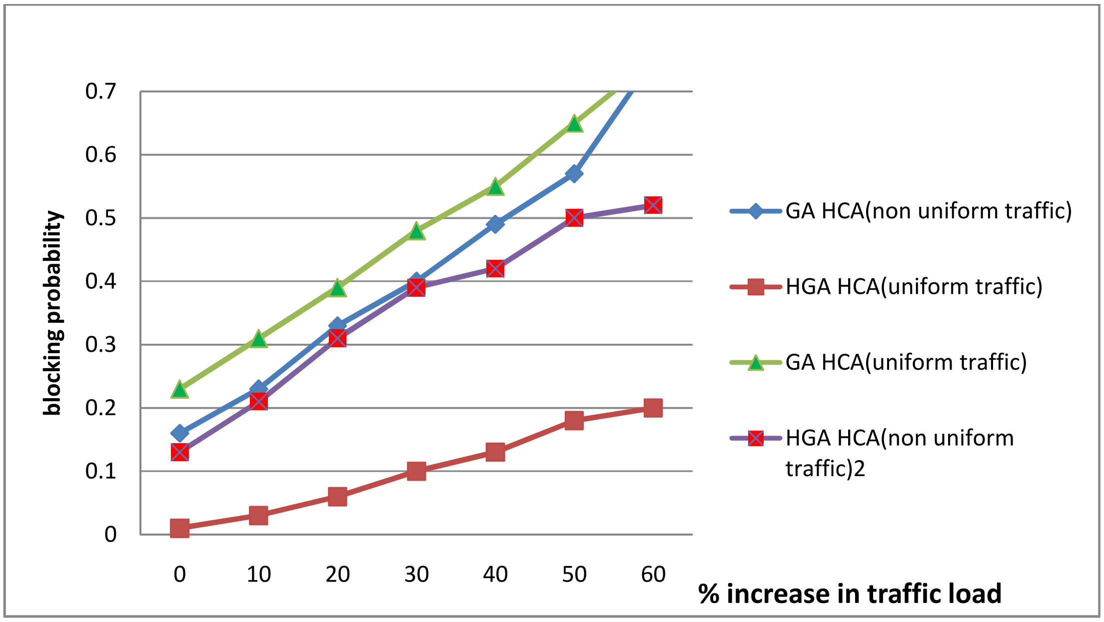


**Fig. 2.** The graph clearly shows superiority of HGA HCA over other schemes.

## VI. CONCLUSION AND FUTURE WORK

This paper demonstrates the application of heuristic algorithms to solve NP hard problems arising in wireless communication systems. This study has considered Hybrid Genetic Algorithm as an optimization algorithm to achieve the research objective to solve the realistic problem of channel allocation for GSM cellular networks.

The hybridization of Genetic Algorithm with Simulated Annealing gives improved performance in terms of SNR.

It is demonstrated that the SNR level close to 40 dB is achieved in all the simulation. This level of SNR provides superior quality of communication. In this we have easily allocate the channels according to the need of SNR and frequency reuse distance with the help of GA and at last we have seen that with the help of limited number of frequency channels we fulfill the need of all cells and also the blocking portability is reduced.

Future work will consider other efficient problem mapping schemes such as tree encoding scheme and problem-specific genetic operator to enhance the performance. The fitness function is necessary to drive the evolution of the population toward the optimal solutions, the fitness function successfully involved the desired signal components and the estimator cut-off parameter, thus, a combined optimization is achieved and the need for a separate channel estimator is thus eliminated. However, this combination is very simple and future work will consider other cost functions, which would hopefully produce more promising results Therefore, the GA approach became a first choice for the solutions and also produced very encouraging results. However, if the problem is formulated to a linear programming model when the resource (UB) is allowed to be real value of integer value, other methods such as Mixed Integer Programming can possibly solve the problem in polynomial time. This could be considered in the future work.

## REFERENCES

[1]. Smith K.A, and Palaniswami M, “Static and dynamic channel assignment using neural networks,” *IEEE J. Select. Areas Commun*, Vol. **15,** pp. 238-249, 1997.

[2]. Chen J, Olafsson S, and Gu X, “Observation on using simulated annealing for dynamic channel allocation in 802.11 WLANs,” *Proc. VTC Spring*, pp. 1801-1805, 2008.

[3]. Vidyarthi G, Ngom A., and Stojmenovic I, “A hybrid channel assignment approach using an efficient evolutionary strategy in wireless mobile network,” *IEEE Trans. Veh. Techno*, Vol. **54**, pp. 1887–1895, 2005.

[4]. Zhenhua Yu, Guangwen Yan, Shanwei Lv,” A Modified Immune Genetic Algorithm for Channel Assignment Problems in Cellular Radio Networks”, *IEEE International Conference on Intelligent System Design and Engineering Application*, pp 823-826,2010.

[5]. Kleeman M.P, Seibert B.A, Lamont G.B, Hopkinson, "Solving Multicommodity Capacitated Network Design Problems Using Multiobjective Evolutionary Algorithms" ,*IEEE Transactions on Evolutionary Computation,* Vol. **16**, Issue: 4, pp. 449 – 471,2012.

[6]. Lima M.A. C, Araujo A.F.R, and Cesar A.C., "Dynamic channel assignment in mobile communications based on genetic algorithms," *13th IEEE International Symposium on Personal, Indoor and Mobile Radio Communication*, Vol. **5**, pp. 2204-2208, 2002.

[7]. Yoshino J, and Othomo I, "Study on efficient channel assignment method using the genetic algorithm for mobile communication systems," *Journal Soft Computing – A Fusion of Foundation, Methodologies and Applications*, Vol. **9**, pp. 143-148, 2005.

[8]. San Jose-Reveuelta L.M, "A new adaptive genetic algorithm for fixed channel assignment," Journal Information Sciences, Vol. 1**77**, pp. 2655-2678, 2007.

[9]. Ghosh S.C, Sinha B.P, and Das N, "Channel assignment using genetic algorithm based on geometric symmetry,*" IEEE Trans. Veh. Techno*., Vol. **52**, pp. 860-875, 2003.

[10]. Cuppini M, "A genetic algorithm for channel assignment problems,*" European Trans. Telecom. Rel. Techn*., Vol. **5**, pp. 285-294, 1994.

[11]. Lai W.K, and Coghill G.C, "Channel assignment through evolutionary optimization,*" European Trans. Telecom. Rel. Techn*., Vol. **45**, pp. 91-96, 1996.

[12].Shinde S. R, Chowdhary Dr. G. V, Dhore M. L, "Hybrid Channel Allocation in Wireless Network using Evolutionary Strategy," *IEEE Conf. on Advance Computing*, Vol. **7**, pp. 72-77, Feb 2010.

[13]. Chia Y.S, Siew Z.W, Kiring A, Yang S.S, "Adaptive Hybrid Channel Assignment in Wireless Mobile Network via Genetic Algorithm*",IEEE International Conference on Hybrid Intelligent Systems* ,Vol. **11**, pp. 511-516,2011

[14]. Sivarajan K N, McEliece R J and Ketchum J W, "Channel assignment in cellular radio", *IEEE Veh. Technol. Soc. Conf.*, Vol.**39**, pp. 846-850, May, 1989.

[15]. Sivarajan K N, McEliece R J , and Ketchum, "Dynamic channel assignment in cellular radio," IEEE *Vehicular Technology Conf.*,Vol.**40**, pp. 631– 637, 1990.

[16]. Ngo CY and Li V O K , "Fixed channel assignment in cellular radio networks using a modified genetic algorithm", *IEEE Trans. Veh. Technol*, Vol. **47**, no. 1, pp. 163-172, Feb. 1998.

[17]. Smith K and Palaniswami M, "Static and dynamic channel assignment using neural network", *IEEE Journal on Selected Areas in Communications*, Vol. **15**, no. 2, Feb 1997.

[18]. Kahwa T.J and Georgans N. D, "A hybrid channel assignment schemes in large-scale, cellular structured mobile communication systems," *IEEE Trans. Commun.,* Vol.-**26**, pp. 432–438, 1978.

[19]. Kennedy J, Eberhart R, "Particle Swarm Optimization", *Proceedings of IEEE International conference on Neural Networks*, pp, 1942-1948, 1995.

[20]. Kennedy J , and Eberhart R. C, "Swarm Intelligence", Academic Press, ISBN 1-55860-595-9, (2001).

[21]. Das S, Konar A., Chakraborty U. K, "Improving Particle Swarm Optimization with Differentially Perturbed Velocity", *ACM-SIGEVO Proceedings of Genetic and Evolutionary Computation Conference (GECCO-2005), Washington DC,* June, 2005.

[22]. Ohatkar Sharada Narsingrao, Bormane Dattatraya S," An Approach for Interference Reduction in Cellular Network", *International Conference on Wireless and Optical Communications Networks (WOCN),* Vol.11.pp.1-5, 2014.

[23]. Kumar Deepak, Srinivas K," A Dynamic Channel Assignment in GSM Telecommunication Network Using Modified Genetic Algorithm", 6th *Euro American Conference on Telematics and Information Systems (EATIS),*pp. 1-5, 2012.

[24]. Farahmand Amir massoud and Yazdanpanah Mohammad," Channel Assignment using Chaotic Simulated Annealing Enhanced Hopfield Neural Network",*IEEE 2006 International Joint Conference on Neural Networks Sheraton Vancouver Wall Centre Hotel, Vancouver, BC, Canada,* pp. 16-21, 2006

[25]. Chenl Jiayuan ,Sverrir Olafsson , Xuanye Gu and Yang Yang," A Fast Channel Allocation Scheme Using Simulated Annealing in Scalable WLANs",*IEEE International Conference on Broadband Communications, Networks and Systems*, Vol. **5**, pp.205-211 ,2008.

[26]. Ciornei Irina, and Kyriakides Elias," Hybrid Ant Colony-Genetic Algorithm (GAAPI) for Global Continuous Optimization", *IEEE Transactions On Systems, Man, And Cybernetics—Part B: Cybernetics,* Vol. **42**, No. 1, pp.234-245,February 2012.

[27]. Wei Wen, Yingchun Chen , Muqi Chen," Time-Cost Tradeoff Problem of Human Resources Based on Hybrid GA", IEEE *International Conference on Information Management, Innovation Management and Industrial Engineering (ICIII),* Vol. **2**, pp. 106-109, 2011.

[28]. Xiaonan Yue, Chi-Fai Wong, Chan, S.-H.G.," A Distributed Channel Assignment Algorithm for Uncoordinated WLANs", IEEE Conference on Consumer Communications and Networking Conference (CCNC),Vol.**5**, pp.1-5, 2010.

[29]. Roberto Battiti, Bertossi Alan A, Mauro Brunato, "Cellular Channel Assignment : a New Localized and Distributed Strategy", *Mobile Networks and Applications,* Vol*.* **6,** pp. 493–500, 2001.

[30]. Sa Li, Lipo Wang,"Channel Assignment for Mobile Communications Using Stochastic Chaotic Simulated Annealing", *Springer Connectionist Models of Neurons, Learning Processes, and Artificial Intelligence*, Vol. **2084**, pp. 757-764, 2001.