ISSN 1064-2269, Journal of Communications Technology and Electronics, 2014, Vol. 59, No. 11, pp. 1225–1233. © Pleiades Publishing, Inc., 2014.

THEORY AND METHODS OF SIGNAL PROCESSING

An Optimization Technique for Efficient Channel Allocation in Cellular Network[1]

S. N. Ohatkar and D. S. Bormane

Department of Electronics, JSPM, RajarshiShahu College of Engineering, University of Pune, Pune, India

e-mail: sharada.ok@gmail.com, bdattatraya@yahoo.com

Received November 1, 2013

Abstract—For today's wireless mobile communication systems, efficient use of limited radio spectrum with minimum interferences is required. Itinvestigates an Optimal Genetic Algorithm approach (GA) for Hybrid Channel allocation (NP hard) focusing on reduction in interference in cellular Network. Obtained an interference graph based fitness function to enhance the performance of HCA for interference reduction. It is shown that the use of integer genetic representation for Crossover and mutation operation enhances the speed of GA leading to less computation time. Comparison of proposed method is done with reported literature for KUNZ 4 which results in less co-channel and co-site interference depicted by interfering edges and also number of generations required are less. The result for KUNZ 1, KUNZ 2 and KUNZ 3 are obtained with minimum interference along with computation time.

DOI: 10.1134/S1064226914110175

INTRODUCTION

Growth of wireless/Mobile user population is increasing tremendously. Bandwidth is an important challenge in wirelesses/Mobile computing. Cost of service, bandwidth requirement and interferences reduction can be achieved by efficient reuse of the scarce radio spectrum allocated to wireless/mobile communications. Limited frequency spectrum and increasing demand have lead to a NP hard problem of channel allocation. The basic prohibiting factor in radio spectrum reuse is interference caused by the environment or by other mobile users. Interference can be minimized by deploying efficient radio subsystems and by utilization of channel assignment techniques. In the radio and transmission subsystems, techniques such as use of low noise filters and efficient equalizers, and deployment of efficient modulation schemes can be used to suppress interference and to extract the desired signal. However, co-channel interference caused by frequency reuse is the most restraining factor on the overall system capacity in the wireless networks, and the main purpose of channel assignment algorithms is to make use of radio propagation path loss characteristics to minimize the carrier-to-interference ratio (CIR) therefore increase the radio spectrum reuse efficiency.

A lot of interest on channel/frequency allocation from scientific field and also business community is generated with increasing popularity of wireless communication since optimally using the available channels/frequencies leads to increased traffic capacity, more bandwidth and wider coverage for the established radio networks. In effect channel/frequency allocation problem have been investigated by many researchers. Computational intelligence is an important category of heuristic methods. [1, 2] the Heuristic based algorithms such as Simulated Annealing (SA) [3, 4], Tabu search (TA) [5, 6], and Neural Network [19] suffer from getting stuck to local minima or convergence behavior is strongly affected from the seed used for random number generators. Where as in GA the solution space is efficiently explored in channel allocation problem (CAP) and danger in sticking on a local minimum is lowered.

In this paper GA based HCA technique is proposed. GA is search method based on natural biological evolution process. In this algorithm at each generation a new set of approximations is created by the process of selecting individual based on fitness in the problem domain, then breeding them together using operators borrowed from natural genetics. This process leads to evolution of population of individuals that are suitable to their environments [7–9]. A basic genetic algorithm includes the three fundamental genetic operations, Crossover, Mutation and Selection. Fitness function is used to select the appropriate offspring. In this paper interference graph based fitness function is proposed, which is used to select the appropriate channel with minimum interference.

The approach of solving the Channel Allocation Problem can be, to assign channels to the vertices in such a way that either the total penalty incurred by a

[1] The article is published in the original.

solution (minsum) or maximum penalty incurred by a solution (minmax) is minimized. Its three aspects are Minimum Span Channel Assignment Problems (MS-CAP): assign channels in such a way that no unacceptable interference occurs, and the difference between the maximum and minimum used channel, the span, is minimized, Minimum Blocking Channel Assignment Problems (MB-CAP): assign frequencies in such a way that no unacceptable interference occurs and the overall blocking probability of the network is minimized and Minimum Interference Channel Assignment Problems (MI-CAP): assign frequencies from a limited number of available frequencies in such a way that the total sum of weighted interference is minimized [10]. Intheproposedwork MI-CAP is been formulated.

1. CHANNEL ALLOCATION TECHNIQUES

In cellular network geographical region is separated in small parts called "cell." A Cell has its own base station antenna with Omni directional radiation pattern. Hexagonal nature of a cell is assumed, which is suitable for Omni directional radiation pattern of base station antenna. Mobile stations in a cell requests base station intended for allocating the channels. Base station allocates the channels to mobile stations by means of channel allocation techniques which assign channels to cells in order to reduce call blocking probability and also call dropping probability. There are three Channel allocation techniques which are based on the manner how channels are utilized [1–14].

1.1. Fixed Channel Allocation (FCA)

In FCA channels are assigned to cells at the commencement of system design. Total channels of cellular system are available to every cluster. In a cluster channel distribution is uniform among cells so every cell uses the same predestined channels. FCA has very uncomplicated design and work efficiently for heavy uniform traffic but do not adjust to changing traffic conditions and user distribution. Channel borrowing schemes are used in FCA to utilize the channels in nonuniform traffic distribution.

1.2. Dynamic Channel Allocation (DCA)

FCA is not able to bestow high channel efficiency for the short-term temporal and spatial variations of traffic in cellular systems. DCA scheme has been considered to overcome the drawback of FCA. In DCA all the channels are available with the central pool and are allocated dynamically to the cells as the new call arrives in it. DCA schemes can be divided into centralized and distributed schemes with respect to the type of control they employ [11–14]. DCA requires extra computational efforts for heavy traffic distribution. DCA does not perform better than FCA for heavy traffic. This can be prevailing by HCA.

1.3. Hybrid Channel Allocation (HCA)

In HCA the set of channels are alienated into fixed and dynamic set. Fixed set contains a number of nominal channels and these channels are allocated permanently and are preferred to be used only in the respective cell. Channels from dynamic set are collectively shared by users. When all nominal channels are utilized then channel from dynamic set are allocated. In HCA, fixed to dynamic channel ratio can be changed according to the nonuniform traffic condition and coverage of geographical area [7, 9, 11, 14].

2. INTERFERENCES IN CELLULAR SYSTEM

In tremendous growth of the wireless user population, number of base station required and efficient use of radio spectrum is an important factor to serve geographical area. Minimizing the number of base stations, and hence the cost of service, can be obtained by efficient reuse of the radio spectrum. Same channel/frequency from one cell is reused in other cell, which is at reuse distance from itself. Reused distance D_r is given as

$$D_r = \sqrt{3N_c}R_e, \qquad (1)$$

where R_e is cell radius and N_c is the reuse pattern (the cluster size or the number of cells per cluster). The different types of interferences like co channel, adjacent channel, and co site are due to reusing channels/frequencies [12–14].

2.1. Co-Channel Interference

It is the radio interference between channels by use of the same frequency. The total suppression of this interference is not possible when frequency reuse concept is applied. To obtain a bearable value of this interference the system designer has to maintain minimum separation distance with respect to the co-channel site. Cells may only exercise the same channels provided that the distance of their centers is equal or multiple of this minimum distance (reuse distance) [13].

2.2. Adjacent Channel Interference

This is the radio interference between channels which are using adjacent frequencies in the adjacent cells. This is caused owing to leakage of frequencies into the pass band because of imperfect filters. The suppression of this kind of interference depends on cautiously filtering and use of guard bands, and also by suitable designing of the cellular system by avoiding adjacent channels to be used.

2.3. Co-Site Interference

This is the radio interference involving channels which are using adjacent frequencies in the same cell. To control this kind of interference proper separation between the channel frequencies is maintained. Reuse of channel by maintaining reuse distance and proper frequency separation can hold back these interfaces and this can be achieved by an efficient algorithm for Channel allocation [14].

3. GENETIC ALGORITHM (GA)

GA is search method based on natural biological evolution process. In this algorithm in every generation a new set of estimate is created by the course of selecting individual based on fitness in the problem domain, then breeding them together using operators borrowed from natural genetics. This process leads to growth of population of individuals that are appropriate to the environment [16]. A basic GA includes the three fundamental genetic operations Crossover, Mutation and Selection.

3.1. Crossover

This operation involves the exchange of genetic material between the two parent strings. In this operation a bit position along the two chromosomes is arbitrarily chosen and the sub-sequences is exchanged before and after the position between two chromosomes to create two offspring. The crossover operator roughly imitates biological recombination between two haploid (single chromosome) organisms [15, 16].

3.2. Mutation

The offspring consequential from each crossover operation are mutated to form the new generation. In the mutation operation one or more bits are altered or flipped from a arbitrarily selected position of chromosome. This operation helps to maintain a adequate level of genetic variety in the population to find the near optimal solution to a given problem [15].

3.3. Selection

Selection of chromosome is based on the survival-of-the-fittest stratagem. The fitness function is used for ranking the quality of a chromosome. A fitness value is assigned to every chromosome by a fitness function and chromosome is evaluated with this price for survival [15].

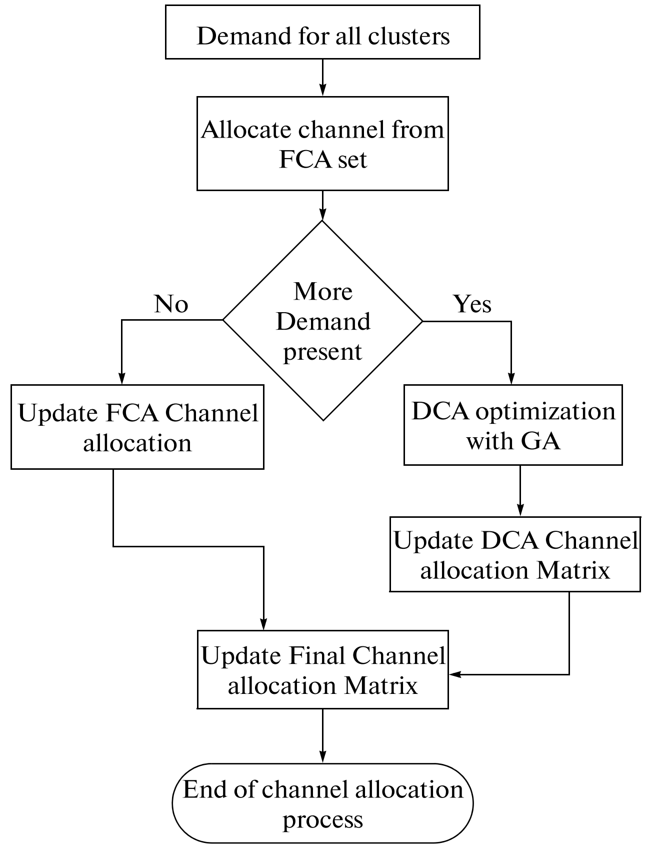

Fig. 1. Simulation of GA based HCA technique.

4. GENETIC DEPICTION

An GA based HCA technique is simulated, initially channels are assigned from FCA channel set, then if the demand is not satisfied channels are allocated from DCA set dynamically using GA. Figure 1 shows the flow for Simulation [17].

4.1. Initial Population

The generation of the initial population for feasible channel allocation solutions is the initial stage of the GA. Two parent vectors are formed in the initial population one for base stations as per the demand and other for existing channels which is given in Eqs. (2) and (3) respectively

$$B_d = B_t - B_f, \tag{2}$$

$$C_d = C_a - C_f. \tag{3}$$

Where B_t is the set of total base stations as per the demand, B_f is the set of base station after allocation of channels, B_d is the set of base station requiring channel, C_a is the set of total available channels in the system, C_f is the set of allocated channels, C_d is the set of available channels.

In every generation of GA channels are assigned from fittest chromosome and B_f, C_f are updated to give fresh population [17, 18].

4.2. Crossover

Crossover probability is to assist parent vector to take best characteristics from each other. Single point location based crossover operator is proposed to reduce the computational charge. Then the channel numbers and base station numbers which are away from the crossover point in both vectors are swapped, which consequences in the child chromosome.

4.3. Mutation

Mutation is an important part of the genetic search as it helps to stop the population from declining at any local optima. This probability of mutation should generally be set quite low, if it is set to high, the search will roll into a primitive random search. Chromosomes are selected to go for mutation as per the mutation probability; base station numbers and channel numbers are swapped. The length of parent vector is not affected and does not produce any duplicate base station and channel number.

4.4. Fitness Function

Fitness of the chromosomes is determined by the fitness function. Chromosome which gives best channel for particular base station demand is preferred using fitness function. If same channel is harmonizing with other base station, then its fitness value is calculated by fitness function. Fitness function is based on interference weight matrix. The lowest fitness value is selected in each generation indicating minimum interference.

$$F = \sum_{i=1}^{n} \sum_{j=1, j\neq i}^{p} EW_{C_i A_j} \frac{1}{D_{ij}} + \sum_{k=1}^{n} \sum_{l=1, l\neq k}^{n} EW_{C_k C_l} \frac{1}{D_{kl}}, \quad (4)$$

where n is the total number of chromosomes, p is the total number of cells in model, C is the set of chromosome with base station numbers, A is the set of all base stations, D_{ij} and D_{kl} are the distances between cell i, cell j and cell k, cell l respectively, EW is the electromagnetic interference (EMI) weight matrix.

5. CELLULAR TRAFFIC MODEL

The heuristics have been tested by many researchers using well-known benchmark instances like Philadelphia, EUCLID, CALMA, 49 cell, KUNZ 4, KUNZ 3,KUNZ 2,KUNZ 1 for allocating the channels with three aspects MS-CAP, MB-CAP and MI-CAP. CALMA and KUNZ are considered for MI-CAP. In 1991 Kunz [19] proposed the first Hopfield model (typical applied with neural network) to find adequate solutions for the FAP problem, including co-channel and co-site interference constraints with parallelogram cell structure as a combinatorial problem. Kunz's model, however, required a large number of iterations in order to reach the final solution.

In this paper the interfering edges are found for KUNZ 1 to KUNZ 4 and KUNZ 4 results are compared with [22].

5.1. Proposed Cellular Traffic Model

The cellular topological model is having form of an parallelogram structure which consists of 25 hexagonal cells, with equal number of cells along both axes. There are 73 channels available in this model to be allocated for received calls (KUNZ 4). In this proposed scheme, the co-channel cells are located with a reuse distance of 3 units with co-site constraints as 4. The simulation call traffic distribution can be either uniform or with nonuniform distribution. Uniform cellular traffic distribution indicates that every cell has the same traffic demand. On the other hand, nonuniform cellular traffic distribution indicates that there is different traffic demand/load in each cell.

5.2. Create Interference Graph for Base Stations

In the cellular traffic model, interference graph of base station is prepared based on graph theory algorithm. Some basic definitions of graph theory associated to simulation model

(i) Each cell corresponds to a vertex. V-set of vertices i.e. set of base stations.

(ii) A forbidden set 'C' is a group of cells all of which cannot use a channel simultaneously.

(iii) A set which is not forbidden is independent called 'I'. A group of cells using the same channel cannot be forbidden. Hence, any group of cells which may use the same channel simultaneously forms an independent set of the underlying graph.

(iv) An edge exists between two vertices if and only if the distance between the corresponding cells is less than the reuse distance.

(v) As per reuse distance number of independent sets varies. Every cell has a co channel cell present at a reuse distance. Independent set is a set of co-channel cells [20]. In this simulation model 3 units is the reuse distance so there are 3 independent sets. Figure 2 shows the 3 colour for cells belongs to 3 independent set.

Interference graph of base station indicates edges between base stations which are not allowed to share same channel [21]. Figure 2 shows the interference graph for base stations. Edge between the base stations

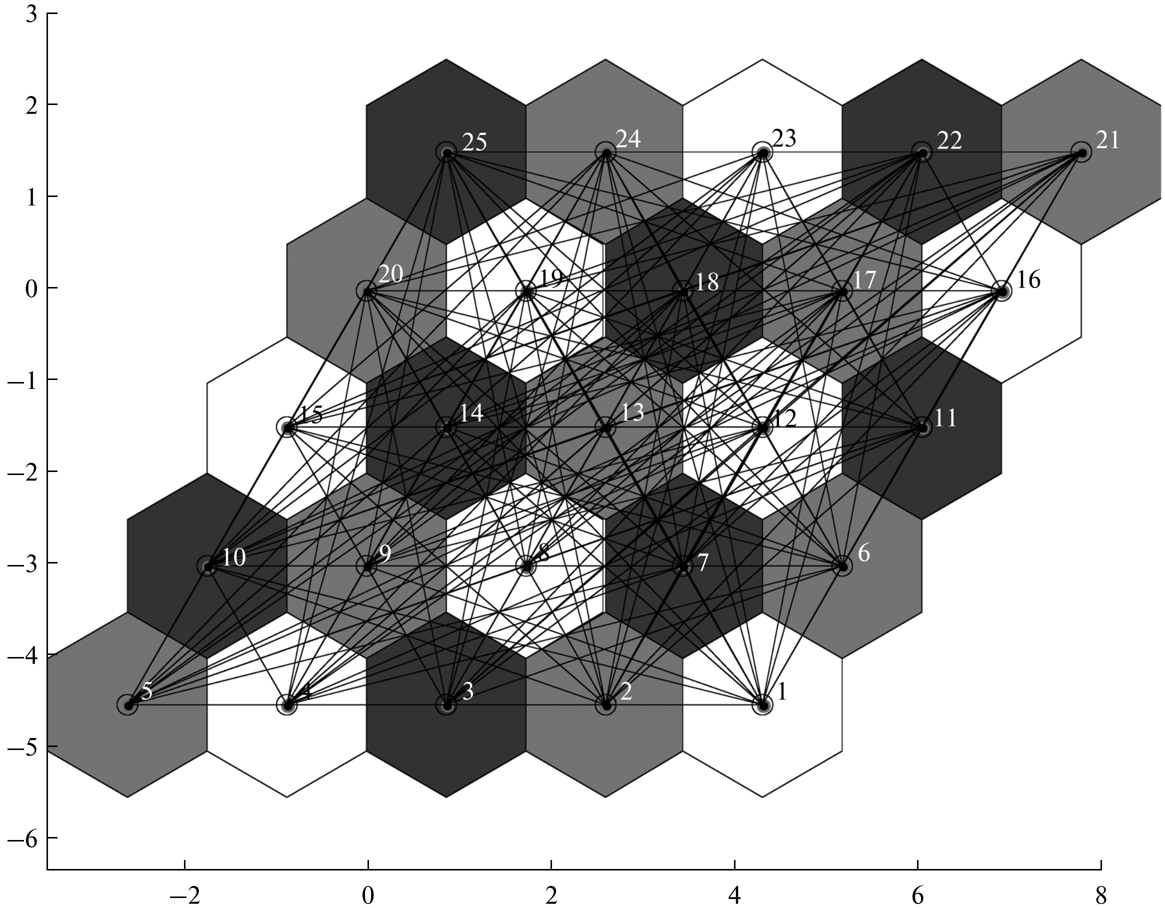

Fig. 2. Interference graph for base stations KUNZ 4.

indicates the interference between them after sharing same channel. Every interference edge has weight depending up on three constrains. These three contains are co channel, adjacent channel and co site. Interference weight matrix represents weight of every edge of interference graph for base station.

5.3. Interference Weight Matrix for Base Stations

EW is an interference weight matrix. It is $N \times N$ matrix and is based on different EMC where *N* is number of cells in cellular model. Each non-diagonal element EW_{ij} represents the weight value, if same channel is assigned between any two cells i and j, respectively. In this matrix, referring Fig. 3, weight of edge among base stations after allotment of same channel is given as

$EW_{ij} = 1$ for Co-channel constraint

$EW_{ij} = 3$ for Adjacent channel constraint

$EW_{ij} = 4$ for Co-site constraint and

$EW_{ij} = 2$ for cells, which are not co-channel and adjacent channel.

6. SIMULATION RESULT

Channel allocation matrix given in [22] for Kunz 4 is plotted for 25 cells and 73 channels in Fig. 4 and its interference graph in Fig. 5.

In Fig. 5 the solid edges indicates co-site interference. In cell if channel are allocated with span less than 4 then it marks the solid edge. Doted edges indicates co-channel interference. If channels are allocated in non co-channel cells which are at distance less than reuse distance, then it is marked with doted edge.

Channel allocation matrix with the proposed method for Kunz 4 is in Fig. 6 and its interference graph in Fig. 7.

It states that in interference graph for channel allocated by proposed method has less number of solid edges (co-site interference) and doted edges(co-channel interference) then [22].

Table 1 shows the details of benchmark worked on. Below Table 2 displays the result for KUNZ 4 as per [22]. The results for KUNZ 1,2 and 3 are derived by

4	3	1	2	3	3	2	2	1	2	1	2	2	2
3	4	2	1	3	3	2	2	2	1	2	1	2	2
1	2	4	3	2	2	3	3	1	2	1	2	2	2
2	1	3	4	2	2	3	3	2	1	2	1	2	2
3	3	2	2	4	3	1	2	2	2	2	2	1	2
3	3	2	2	3	4	2	1	2	2	2	2	2	1
2	2	3	3	1	2	4	3	2	2	2	2	1	2
2	2	3	3	2	1	3	4	2	2	2	2	2	1
1	2	1	2	2	2	2	2	4	3	1	2	3	3
2	1	2	1	2	2	2	2	3	4	2	1	3	3
1	2	1	2	2	2	2	2	1	2	4	3	2	2
2	1	2	1	2	2	2	2	2	1	3	4	2	2
2	2	2	2	1	2	1	2	3	3	2	2	4	3
2	2	2	2	2	1	2	1	3	3	2	2	3	4
2	2	2	2	1	2	1	2	2	2	3	3	1	2
2	2	2	2	2	1	2	1	2	2	3	3	2	1
1	2	1	2	2	2	2	2	1	2	1	2	2	2

Fig. 3. Interference weight matrix for base stations.

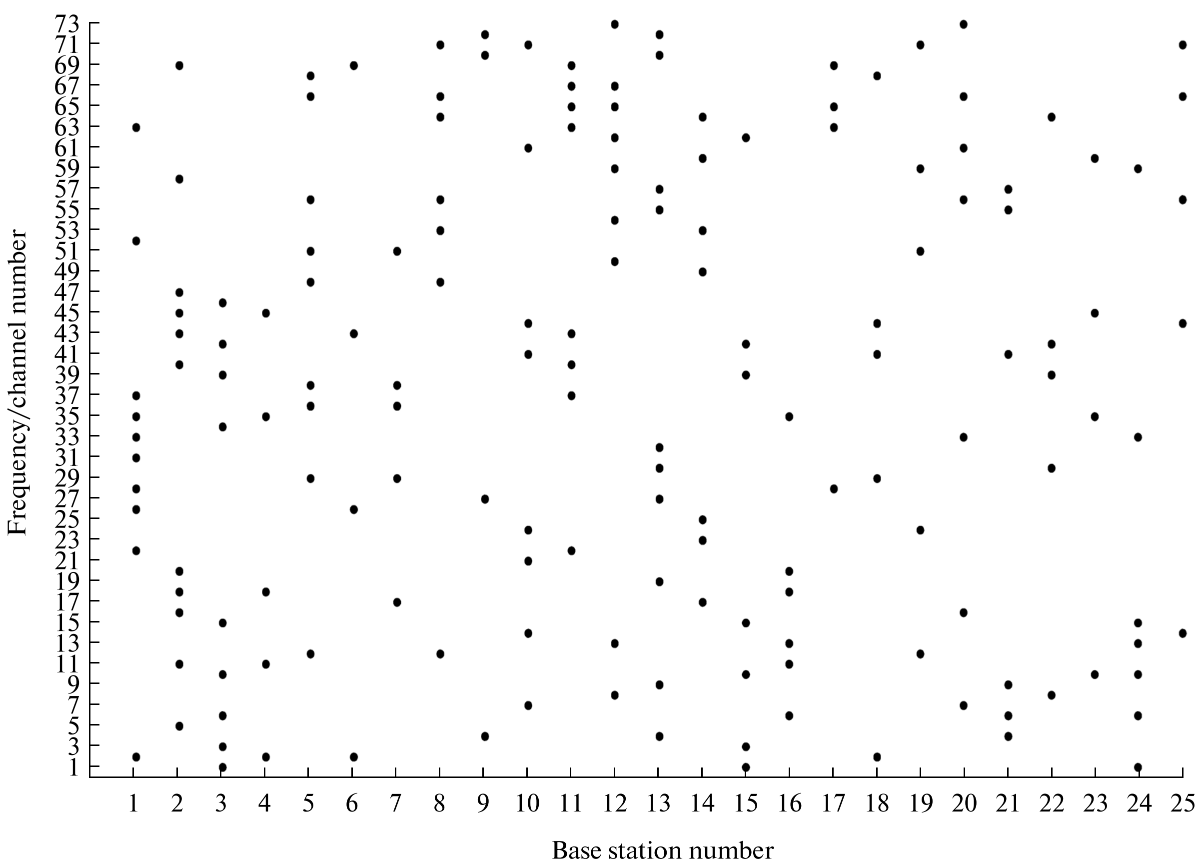

Fig. 4. Channel allocations in [22] for KUNZ 4.

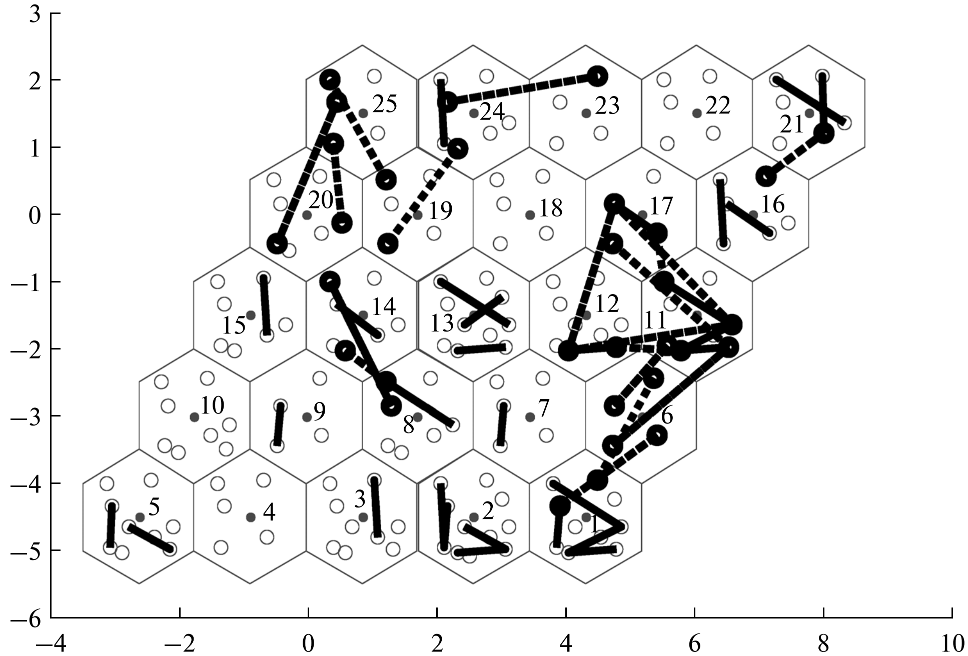

Fig. 5. Interference graph by [22] for KUNZ 4.

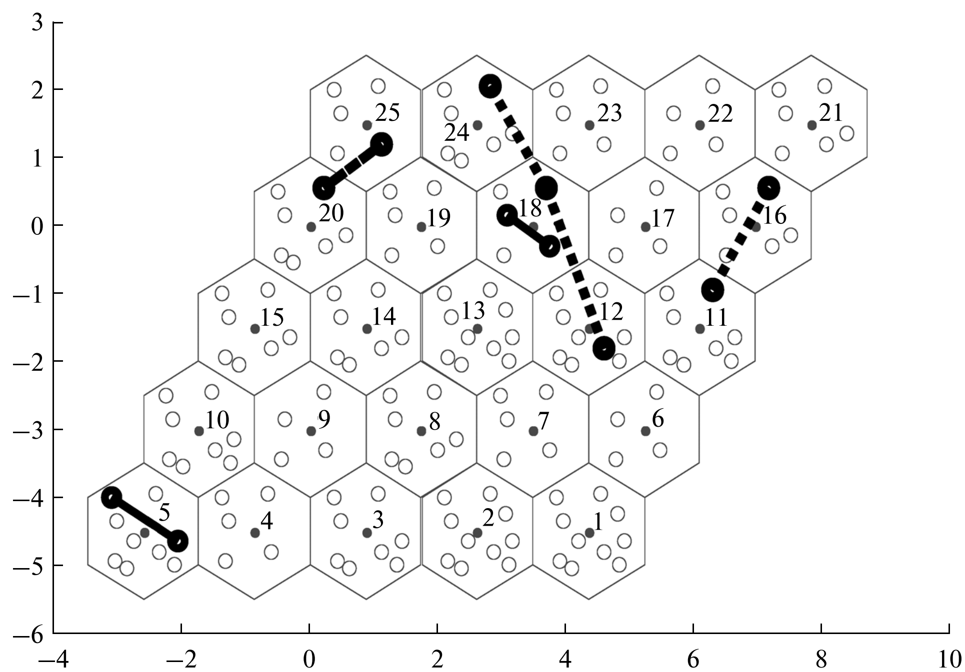

Fig. 6. Interference graph with proposed method for KUNZ 4.

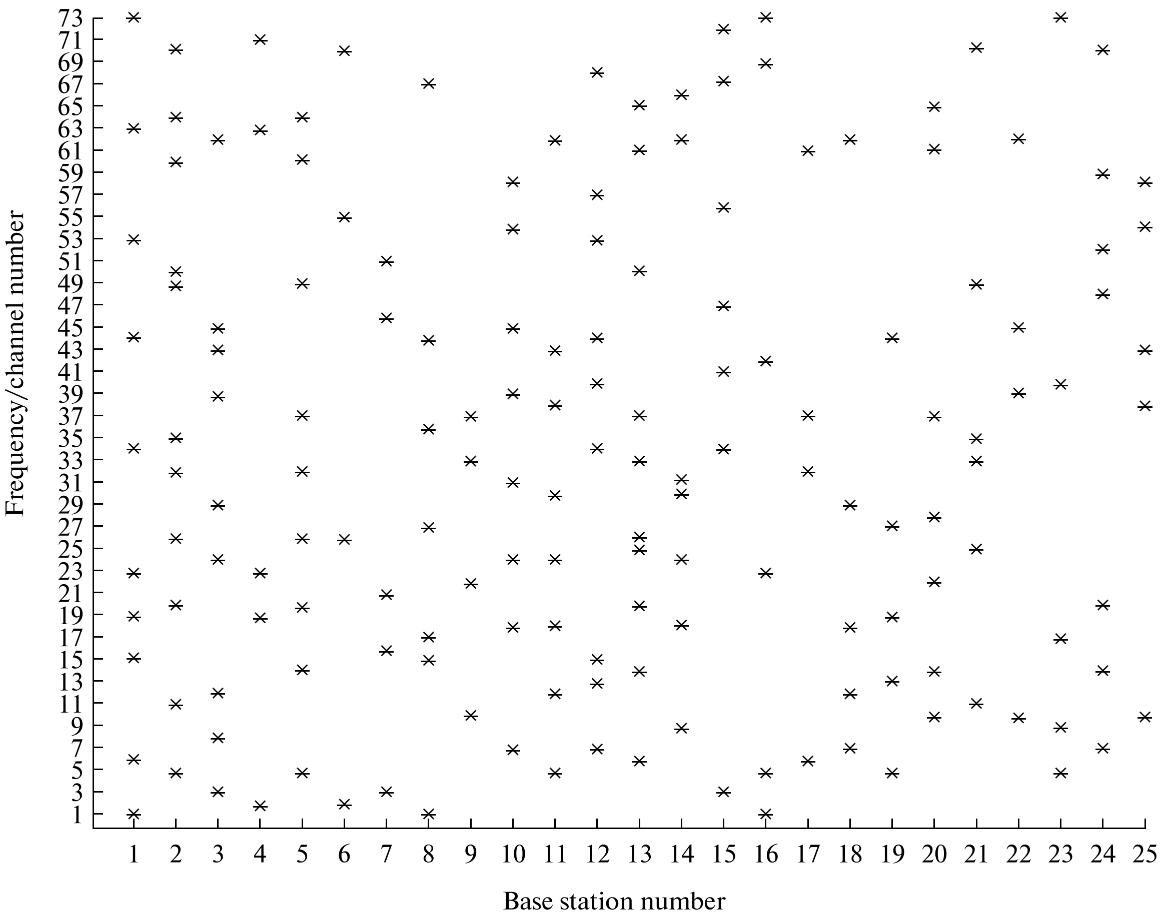

Fig. 7. Channel allocations with proposed method (KUNZ 4).

the same process. The simulated results for the proposed method in presented in Table 3.

The reported result for KUNZ 4 in [22] when compared with the proposed method depicts less number of interfering edges along with very less number of generations required for total demand satisfaction. The computation time is also found out. For simulation we had used a workstation with OS Windows 7 on a core I3 (second generation) processor, 3.5 GHz speed and 2 GB RAM. The simulation is done using MATLAB.

Table 1. Benchmark Details

Problem	Cells	Channel	Demand
KUNZ 1	10	30	10,11,9,5,9,4,4,7,4,8
KUNZ 2	15	44	10,11,9,5,9,4,4,7,4,8,8,9,10,7,7
KUNZ 3	20	60	10,11,9,5,9,4,5,7,4,8,8,9,10,7,7,6,4,5,5,7
KUNZ 4	25	73	10,11,9,5,9,4,5,7,4,8,8,9,10,7,7,6,4,5,5,7,6,4,5,7,5

Table 2. Interfering Edges [22]

Problem	Cochannel	Cosite	Generations required
KUNZ 4	18#	29#	2450# 12.25*
KUNZ 3	58	21	50000 to 100000#
KUNZ 2	32	27	–
KUNZ 1	32	21	–

[22].
* In units of the low-pass time constant.

Table 3. Interfering edges with proposed method

Problem	Cochannel	Cosite	Generations required	Computation time (in sec)
KUNZ 4	4	2	248	0.7696
KUNZ 3	3	2	200	0.5191
KUNZ 2	0	3	200	0.5191
KUNZ 1	0	19	200	0.5191

CONCLUSIONS

In this paper HCA technique based on GA with interference graph based fitness function is projected which is found to be efficient function for interference reduction. The proposed method is applied to KUNZ 4, KUNZ 3, KUNZ 2 and KUNZ 1 benchmark instance and the interfering edges are determined indicating co-channel and co-site constraints. The proposed method is compared for KUNZ 4 with the reported result for the same benchmark is found to be having less number of interfering edges along with the number of iterations/generations required for satisfying the total demand are quite less i.e. 248 as compared with 2450 of the result reported in [22]. The computation time required for the simulation is also quite low.

The efficiency of the proposed method needs to be explored further with real–life MI-CAP instance and other challenging benchmarking instances like CALMA or CELER. The GA presented applied one-point crossover which may be improved with order crossover or partially matched crossover.

REFERENCES

1. M. P. Mishra and P. C. Saxena, Int. J. Networks Commun. **2** (5), 75 (2012).
2. I. A. Karen, P. M. Stan van Hoesel, et al., *Springer Science and Business Media* LLC, (2007).
3. M. Hellebrandt and H. Heller, *Technical Report TD 003 COST 259* (Valencia, Spain, 2000).
4. P. Björklund, P. Värbrand, et al., Comput. Oper. Res. **32**, 169 (2005).
5. P. Galinier, M. Gendreau, et al., Quart. J. Oper. Res., **3**, 59 (2005).
6. R. Montemanni, J. N. J. Moon, et al., IEEE Trans. Veh. Technol. **52**, 891 (2004).
7. G. Vidyarthi, A. Ngom, et al., IEEE Trans. Veh. Technol. **54**, 1887 (2005).
8. S. Ali, A. Fakoorian, and H. Taheri, in *Proc. IEEE 2nd Conf. on Next Generation Internet Design and Engineering, Valencia, Apr. 3–5, 2006* (IEEE, New York, 2006).
9. M. Alabau, L. Idoumghar, et al., IEEE Trans. on Broadcast, **48**, 27–34 (2002).
10. http://fap.zib.de/
11. A. M. C. A. Koster, PhD Thesis, (Maastricht Univ., Maastricht, 1999).
12. W. C. Y. Lee, *Mobile Cellular Telecommunications Systems* (McGraw Hill, New York, 1989).
13. A. Mehrotra, *Cellular Radio, Analog and Digital Systems* (Artech. House, Boston-London, 1994).
14. J. Schiller, *Mobile Communications* (Addison–Wesley, 2003).
15. I. Amro and W. Ghanem, in *Proc. 5th Int. Conf. Genetic and Evolutionary Computing, San Francisco, CA, USA, July 7–11, 2001* (Morgan Kaufmann Publishers, San Francisco, 2011).
16. A. A. R. Townsend, *A Genetic Algorithm: Tutorial* (July, 2003).
17. M. I. Majid, M. A. Imran et al., in *Proc. IEEE 21st Int. Symp. on Personal Indoor and Mobile Radio Commun., (PIMRC 2010), Istanbul, Sept. 26–29, 2010* (IEEE, New York, 2010).
18. Y. S. Chia, Z. W. Siew et al., in *Proc. IEEE 11th Int. Conf. on Hybrid Intelligent System (HIS), Cordoba, 2011* (IEEE, New York, 2011).
19. D. Kunz, IEEE Trans. Veh. Technol. **40**, 188 (1991).
20. Evi Papaioannou, PhD Thesis (Univ. of Patras, Greece, 2004).
21. T. Hiroshi, S. Masakazu, et al., in *Proc. 2011 Int. Tech. Conf. Circuits/Systems, Computers and Comm. (ITC-CSCC 2011), Hyundai, June 19–22, 2011* (Inst. Electron. Engineers Korea, 2011), p. 57.
22. L. Wang, Sa Li, et al., PhD Thesis, (School of Electrical and Electronic Engineering, Nanyang Technological University, 2006).