International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:8, No:2, 2014

A New Reliability Based Channel Allocation Model in Mobile Networks

Anujendra, Parag Kumar Guha Thakurta

***Abstract*—**The data transmission between mobile hosts and base stations (BSs) in Mobile networks are often vulnerable to failure. So, efficient link connectivity, in terms of the services of both base stations and communication channels of the network, is required in wireless mobile networks to achieve highly reliable data transmission. In addition, it is observed that the number of blocked hosts is increased due to insufficient number of channels during heavy load in the network. Under such scenario, the channels are allocated accordingly to offer a reliable communication at any given time. Therefore, a reliability-based channel allocation model with acceptable system performance is proposed as a MOO problem in this paper. Two conflicting parameters known as Resource Reuse factor (RRF) and the number of blocked calls are optimized under reliability constraint in this problem. The solution to such MOO problem is obtained through NSGA-II (Non dominated Sorting Genetic Algorithm). The effectiveness of the proposed model in this work is shown with a set of experimental results.

***Keywords*—**Base station, channel, GA, Pareto-optimal, reliability.

I. Introduction

A cellular network is divided into a number of geographical regions called cells, which are usually hexagonal for analytical and experimental purposes. In each cell, a base station (BS) is placed for transmitting as well as receiving calls. Therefore, the BS provides an end point connection for servicing the mobile hosts (MHs). These BSs are interconnected with each other through a mobile switching centre (MSC) by wired or wireless media. In practice, such wireless channels are not sufficient enough to provide huge user demand and therefore, it needs to be reused to provide an optimal resource. Hence, an effective resource management in mobile computing discipline would become a challenging task.

The channel reuse concept is used in the channel allocation problem (CAP) to assign optimal resources for communicating with MHs. In this approach, the same channel is used by different MHs which are separated by a minimum distance [1] to avoid cochannel interference. Generally, there are two phases of a channel-allocation algorithm known as *channel acquisition* and *channel selection*. The task of the first one is to collect the information of free available channels from the interference cells and ensure that the two cells within the minimum reuse distance do not share the same channel. The next phase deals the selection of one from the acquired channels in previous with improved performance [2].

This CAP is discussed in [3] from the view point of reliability aspect for the system. Generally, the reliability determines the ability of a system to successfully perform its functions in hostile circumstances. Technically, it measures the probability that the network performs its intended function for a given time period under normal environmental conditions. In essence, the unreliability of a connection is defined as the probability that the experienced outage probability for the connection is larger than a predefined maximum tolerable value. Thus, the reliability issue in CAP addresses an importance in mobile computing. In context of the reliability based CAP, the application of Genetic Algorithm (GA) has been used as a problem-solving tool to a large extent. It has been successfully implemented for that optimization problem in which no straightforward solution exist. Under consideration of such tool in [4]-[8], it has been observed that the reliability service for CAP is improved accordingly with satisfying the user's demand.

In short, several analyses on reliability based CAP has been carried out with multiple design objectives. Most of them resolved optimality using only objective function(s), whereas we have introduced reliability based constraint along with MOO problem for finding optimal resources for the network. The utility of such constraint lies in fine tuning the network performance.

In this paper, a multi objective optimization (MOO) problem on reliability based channel allocation for mobile networks is proposed. Two conflicting parameters known as *Resource Reuse factor (RRF)* and the *number of blocked calls* are considered as objectives in this problem. These two factors are optimized accordingly with satisfying proposed reliability based constraint. This MOO problem is discussed on aspect of reliability measure for the system. To obtain a reasonable solution for such MOO problem, NSGA-II (Non dominated Sorting Genetic Algorithm) concept has been used over other approaches due to its reduced time complexity. The effectiveness of the proposed model in this work is shown with a set of experimental results.

The rest of this paper is organized as follows. In Section II, a brief introduction to MOO problem and its solution, the concept on evolutionary algorithms, and a brief introduction on NSGA-II are discussed. The model proposed in this paper has been described in Section III. Next, the performance of the proposed model is evaluated by carrying out the simulation experiments in Section IV. Finally, the conclusions are made with its future scope in Section V.

Anujendra is with the National Institute of Technology, Durgapur, WB-713209, India (e-mail: anujendra@ gmail.com).

Parag Kumar Guha Thakurta is with the National Institute of Technology, Durgapur, WB-713209, India (e-mail: parag.nitdgp@gmail.com).

II. Related Terminologies

Before presenting the proposed model, some useful terminologies related to our work are described for completeness of the work as follows.

MOO Problems [10]

In various real-life problems, objectives under consideration may conflict with each other. In such scenario, optimizing a particular solution with respect to one objective may be unacceptable with respect to another objective. Here, a set of solution for such MOO problem is explored, each of which satisfies the objectives at an acceptable level without being dominated by any other solution. This set of solutions is called a Pareto-optimal solution.

B. Evolutionary Algorithms [12]

Generally, there are two methods to obtain Pareto optimal solution for MOO known as traditional methods and evolution algorithms. In traditional method, all objectives are aggregated into single objective and hence, expressed as a single objective problem. Some difficulties have been observed in case of traditional method due to its behavior. These are – (i) Obtained solutions can't converge to non-convex Pareto-optimal set, (ii) Every solution is independent with each other, and it needs larger computational time to execute and (iii) Many useful Pareto-optimal solution may be lost due to different weight vector assigned by different decision maker. On the other hand, the Evolution Algorithm (EA), including Genetic Algorithm (GA) can provide Pareto optimal solutions at one time for a MOO problem.

C. Genetic Algorithm (GA) and NSGA-II [11]

In the field of computer science, the genetic algorithm (GA) belonging to the larger class of EA is used as a heuristic search procedure to generate solutions for MOO problem using techniques, such as inheritance, mutation, selection, and crossover.

The GA is well suited for solving MOO problems as it is a population-based approach. The single objective GA is modified to provide a set of multiple non-dominated solutions in a single run. In effect, the GA can simultaneously search different regions of a solution space to make a diverse set of solutions. One of such multi objective genetic algorithm (MOGA) based algorithm is NSGA-II. It is a non-dominated sorting-based multi-objective evolutionary algorithm with a computational complexity of $O(MN^2)$, where M and N denote the number of objectives and the population size respectively. Due to its low computational requirements, elitist features and constraint handling capacity, it has been successfully used in many applications.

III. Proposed Model

The model proposed in this paper describes a reliability based channel allocation method for mobile networks through GA approach. Initially, the system model related to the proposed work is presented as follows.

A. System Model

The basic CAP model [9] is used to illustrate the system model for the proposed work under standard hexagonal cellular layout of mobile networks. A set X of n distinct cells is assumed with cell numbers$0, 1, \ldots, n-1$. In addition, a demand vector $M = (m_i), 1 \leq i \leq n$ is considered to indicate the number of channels required for cell i asm_i .Next, a channel allocation matrix (CA_{alloc}) is defined with each element a_{ik} to denote the assignment of k^{th}channel in i^{th}cell, where $1 \leq i \leq n$, $1 \leq k \leq z$. Here, each channel is represented by binary values 1 or 0 to indicate *"allocated"* or *"not allocated"* respectively. Again, the channel reuse constraint is defined by compatibility matrix C, where each element of C is obtained as $|f_{ik} - f_{jl}| \forall\, i \neq j, k \neq l$. Hence, the CAP is characterised by the triplet (X, m, C). The performance metric respect to the proposed model are described by the following.

1. System Reliability(R_{SYS})

The reliability [3] of the system is dependent on both of the services of BS and channels over a time t during the communication between the hosts and the corresponding BS. This R_{SYS} is expressed as follows.

$$R_{SYS} = R_{BS} \times R_{CH} \tag{1}$$

Here, R_{BS} denotes the reliability of the BS over time t and it is followed by an exponential distribution as the reliability of such BS is invariable over t. Subsequently, R_{BS} is expressed as$e^{-\lambda t}$, where $\lambda$is the failure rate of the BS. Now, if the number of BS used in the system for one whole session is p, then R_{BS} is represented as follows.

$$R_{BS} = e^{-\sum_{k=1}^{p}(\lambda_k t_k)} \tag{2}$$

Similarly, R_{CH} is the reliability measure for $'q'$ number of channels used for one complete session and is expressed as follows:

$$R_{CH} = e^{-\sum_{i=1}^{q}(\mu_i t_i)} \tag{3}$$

where, μdenotes the failure rate of the channels in the system.

2. Resource Reuse factor (RRF)

To allocate the channels as much as possible to each cell, the RRF for the system is expressed as follows.

$$RRF_{SYS} = \frac{R_{SYS}}{n} \sum_{j \in n} \frac{K_j + K_{reuse_j}}{m_j} \tag{4}$$

In (4), the ratio of the sum of channel allocation (K_j) and reused channels (K_{reuse_j}) to the number of channels demand (m_j) is evaluated for each BS (j). The summation of this ratio is subsequently computed to provide the channel allocation for the system. As the proposed model is based on reliability measure, so this summation is multiplied with corresponding

R_{SYS}. Finally, this expression is divided by n to obtain a rounded value of RRF_{SYS}.

Two parameters viz. K_j and K_{reuse_j} are used in (4) to denote the total number of channels allocated to a specific cell and the total number of channels allocated, other than the previously allocated channels, after channel reuse respectively. These parameter values are computed as follows.

$$K_j = \sum_{i \in n} a_{j\,i} \quad and \quad K_{reuse_j} = \sum_{i \in n} a_{j\,i} \qquad (5)$$

3. Blocked Hosts

During heavy load in the network, a huge number of hosts are unable to communicate with others due to insufficient channels. Subsequently, it increases the number of blocked hosts in the network. Therefore, the number of blocked calls is to be optimized to a desired extent. To carry out this task, the fitness function is given as follows.

$$Fitness\ (F) = currently\_blocked - reserved\_channels \qquad (6)$$

In (6), currently_blocked is the total number of hosts blocked at a specific time and the reserved_channels are kept for providing channels during higher load conditions in the network.

B. Problem Statement

During high load in the network, it may lead congestion due to insufficient allocated channels. To efficiently use the number of channels with maintaining reliability measure under such scenario, the objective of the proposed problem in this work is to maximize the value of RRF_{SYS} as much as possible. Simultaneously, the number of blocked calls is minimized through reducing the value of F to obtain efficient channel reuse. Therefore, the MOO problem in this work is proposed as follows.

$$Objective: \begin{cases} \max RRF_{SYS} \\ \min(F) \end{cases} \qquad (7)$$

Subject to

$$R_{SYS} \leq 1 \qquad (8)$$

In (8), the R_{SYS} value is regulated in such a way that the objectives in (7) are satisfied with the value of R_{SYS} closest to 1 for making reliable communication according to the user's demand.

C. Proposed Solution

The problem proposed in this work is solved by GA approach. It uses NSGA-II concept to get the solution, rather than other approaches of MOGA, due to its reduced time complexity as well as generating a set of Pareto optimal solution in a single run.

In the proposed work, the chromosome is considered as a sequence of channels comprising of two types-"*allocated and not allocated*". The population index is initialized as 0. Here, the genetic operators such as selection, crossover, and mutation are applied to create the offspring population (collection of chromosomes) Q_t of size N with improved performance. The function of these operators is described by the following.

- Selection: Selection is a genetic operator that chooses a chromosome from the current generation's population for inclusion in the next generation's population. From the existing selection techniques, tournament selection [13] has been used in this paper. Tournament selection involves running several "*tournaments*" among a few individuals chosen at random from the population. The winner of each tournament (the one with the best fitness) is selected for crossover.
- Crossover: Crossover is a genetic operator used to vary the programming of a chromosome or chromosomes from one generation to the next. From the many existing crossover techniques, two-point crossover has been used to obtain better allocated channels with satisfying both objective functions in (7).

Example I: Considering, two channel allocation matrices are CH_1 and CH_2 from the population. Two sites are randomly selected as $site_1$ = 2 and $site_2$ = 5. Now, the two-point crossover is applied to the matrices and two childrenCH_3 and CH_4 are obtained with improved RRF_{SYS}. This procedure is shown in the following Fig. 1.

CH_1

	0	1	2	3	4	5	6	7
0	1	0	1	1	0	0	0	1
1	0	1	0	1	0	1	0	1
2	1	1	1	0	0	1	1	1
3	1	0	1	0	1	0	1	0

CH_2

	0	1	2	3	4	5	6	7
0	1	1	1	0	1	0	1	1
1	0	0	1	0	1	0	0	1
2	1	1	1	0	0	0	1	1
3	1	0	0	1	1	0	0	1

Crossover

CH_3

	0	1	2	3	4	5	6	7
0	1	0	1	0	1	0	0	1
1	0	1	1	0	1	0	0	1
2	1	1	1	0	0	0	1	1
3	1	0	0	1	1	0	1	0

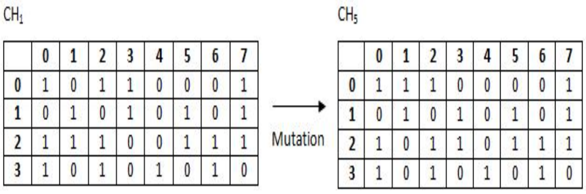
CH_4

	0	1	2	3	4	5	6	7
0	1	1	1	1	0	0	1	1
1	0	0	0	1	0	1	0	1
2	1	1	1	0	0	1	1	1
3	1	0	1	0	1	0	0	1

Fig. 1 Improvement after applying crossover

- Mutation: Mutation is a genetic operator used to maintain genetic diversity from one generation of a population of genetic algorithm chromosomes to the next. In this paper, the probability of mutation is considered to be 0.05 (1/No. of cells), which refers to the probability of a channel to shift from one BS to other. Next, we iterate through the channel list and randomly determine a channel. The two neighbors of the selected channel interchange their "*allocated*" or "*not allocated*" bits i.e. for any two channels *X* and *Y*, channel *X* will now provide service to the cells where channel *Y* was providing and vice versa.

Example II: Considering again CH_1 and then mutation operator is applied on it to produce CH_5 and shown in Fig. 2.



CH1

	0	1	2	3	4	5	6	7
0	1	0	1	1	0	0	0	1
1	0	1	0	1	0	1	0	1
2	1	1	1	0	0	1	1	1
3	1	0	1	0	1	0	1	0

CH5

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	0	1
1	0	1	0	1	0	1	0	1
2	1	0	1	1	0	1	1	1
3	1	0	1	0	1	0	1	0

Fig. 2 Mutation applied

The procedure of the generation of offspring population with improved fitness value is described by the following algorithm.

NSGA-II ( ){
Index i=0
Initialize P_0 population of size N;
do {
for j = 1 to N
$Y_{parent1}$ ← TournamentSelection (P_i) /*selecting first parent*/
$Y_{parent2}$← TournamentSelection (P_i) /*selecting second parent*/
Q_i← crossover ($Y_{parent1}$, $Y_{parent2}$, C_p) /*crossover with crossover probability Cr*/
Mutation (Q_i,M_p) /*M_p is the mutation rate*/
End for
R_i = P_i U Q_i/*combining parent and offspring population to form R_I of size 2N*/
F = fast-non-dominated-sort (R_i) /*non dominated fronts of R_i*/
P_{i+1} = φ /*initialize P_{i+1} to φ */
For (j=1;P_{i+1} + F_i<= N; j++)
assign-crowding-distance (F_j)
P_{i+1} = P_{i+1} U F_j/*include j^{th} non dominated front in the parent population*/
End for
Sort (F_j) /*sort F_i in descending order*/
P_{i+1} = P_{i+1} U F_j[1 to (N - |P_{i+1}|)] /*include the (N - |P_{i+1}|) elements of F_j*/
i++; /*increment the generation count by 1*/
}
Until $(i <= G)$ /*termination condition: G denotes the total number of generations*/
Return P_i
}

IV. Experimental Evaluation

The performance of the proposed work is evaluated in this section. The experiment is conducted up to 100 generations to converge the solution. The experiments have been designed by writing programs in C language.

(i) Experimental Set up: The simulation parameters used in the experiment are listed as follows.

- The simulated cellular network consists of 20 cells.
- The total number of channels and hosts in the network are varying.
- The reserved channels, for all the experiments, are 25% of the total number of channels.

(ii) Simulation Results: The results are represented in the following performance graphs in Figs. 3 (a)-(d), where the x-axis represents the number of blocked calls and the y-axis denotes Resource Reuse Factor (RRF_{SYS}) values. In these figures, it has been observed that the number of blocked calls is reduced significantly with increasing values of resource reuse factor from $G = 1$ to $G = 100$ for 100 and 1000 number of channels respectively.

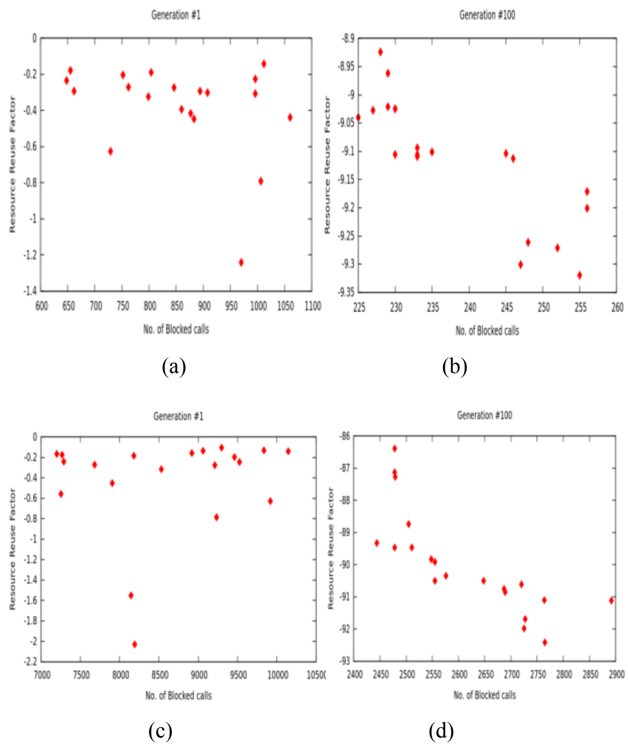
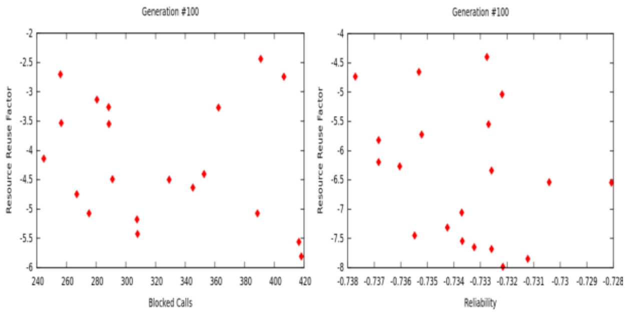


Fig. 3 Performance: (a) and (b) 100 number of channels, (c) and (d) 1000 number of channels

In Figs. 3 (a)-(d), the reliability values are taken higher as much as possible. Now, the number of blocked calls is increased due to reduced reliability values as shown in Fig. 4 (a). However, Fig. 4 (b) shows the behavior of resource reuse factor with respect to reliability with the values of λ and μ taken as 0.001 to 0.01 and 0.01 to 0.03 respectively.



(a) (b)

Fig. 4 Performance of the system with respect to reliability: (a) reduced reliability measure, (b) resource reuse measure with respect to reliability

V. Conclusions

The reliability based channel allocation model for mobile networks is proposed in this paper. This model uses the GA approach to optimize both objectives such as number of channels and the number of blocked hosts. However, the solution for this MOO problem proposed in this paper is obtained by satisfying reliability constraint. Thus, the proposed model is an effective approach to make the network connections more reliable. It has been observed that the well-managed and efficient usage of the channel reuse factor known as RRF greatly increases the number of channels to avoid congestion in the network. The performance of the proposed model has been evaluated by conducting the simulation experiment.

References

[1] J. Yang, Q. Jiang, D. Manivannan, and M. Singhal, "A fault-tolerant distributed channel allocation scheme for cellular networks", IEEE Transactions on Computers, Vol. 54, No. 5, May 2005, pp.616–629.
[2] M. Gupta and A. K. Sachan, "Distributed dynamic channel allocation algorithm for cellular mobile network", Journal of Theoretical and Applied Information Technology, Vol. 3, No. 3, 2007, pp.58–63.
[3] Lutfi Mohammed Omer Khanbary and Deo Prakash Vidyarthi, "Reliability-based channel allocation using genetic algorithm in mobile computing", IEEE Transactions on Vehicular Technology, Vol. 58, No. 8, October 2009, pp.4248-4256.
[4] S. S. Mahapatra, K. Roy, S. Banerjee, and D. P. Vidyarthi, "Improved genetic algorithm for channel allocation with channel borrowing in mobile computing", IEEE Transactions on Mobile Computing, Vol. 5, No. 7, Jul 2006, pp.58–63.
[5] A. K. Tripathi, D. P. Vidyarthi, and A. N. Mantri, "A genetic task allocation algorithm for distributed computing system incorporating problem specific knowledge", International Journal of High Speed Computing, Vol. 8, No. 4, 1996, pp.363–370.
[6] S. H. Wong and I. Wassell, "Dynamic channel allocation using a genetic algorithm for a TDD broadband fixed wireless access network", IASTED International Conference in Wireless and Optical Communications, Banff, Canada, July 2002; pp.521–526.
[7] I. E. Kassotakis, M. E. Markaki, and A. V. Vasilakos, "A hybrid genetic approach for channel reuse in multiple access telecommunication networks", IEEE Journal on Selected Areas in Communications, Vol. 18, No. 2, Feb. 2000; pp.234–243.
[8] M. Asvial, B. G. Evans, and R. Tafazolli, "Evolutionary genetic DCA for resource management in mobile satellite systems", Electronics Letters, Vol. 38, No. 20, Sep. 26, 2002; pp.1213–1214.
[9] Xiannong Fu, Anu G. Bourgeois, Pingzhi Fan and Yi Pan, "Using a genetic algorithm approach to solve the dynamic channel-assignment problem", International Journal Mobile Communications, Vol. 4, No. 3, 2006, pp.333-353.
[10] DeoVidyarthi and Lutfi Khanbary, "Multi-objective optimization for channel allocation in mobile computing using NSGA-II", International Journal of Network Management 2011, pp.247–266.
[11] Kalyanmoy Deb, Amrit Pratap, Sameer Agarwal and T. Meyarivan, "A fast and elitist multiobjective genetic algorithm: NSGA-II", IEEE Transactions on Evolutionary Computation, Vol. 6, No. 2, April 2002, pp.182-197.
[12] Yi Hong-Xia; Xiao Liu; Liu Pu-Kun, "Intelligent Algorithms for Solving Multiobjective Optimization Problems," 4th International Conference on Wireless Communications, Networking and Mobile Computing, 2008. WiCOM '08, pp.1,5, 12-14 October 2008.
[13] David E. Goldberg and Kalyanmoy Deb, "A Comparative Analysis of Selection Schemes Used in Genetic Algorithms", in: G.J.E. Rawlins (Ed.), Foundations of Genetic Algorithms, Morgan Kaufmann, Los Altos, 1991, pp. 69-93.

Anujendra is currently pursuing M. Tech in Computer Science and Engineering from the National Institute of Technology, Durgapur, India. He received the B.Tech degree in Computer Science and Engineering from the University Institute of Engineering and Technology, Kanpur, India, in 2012.

He is ACM student member since 2013. His research interests include wireless mobile computing and applications of evolutionary computation.

Parag Kumar Guha Thakurta is currently working as an assistant professor in the Department of Computer Science & Engineering at National Institute of Technology, Durgapur, India. His research interest includes mobile networks and evolutionary computing etc.