A New Evolutionary Approach for Base Station Transmitter Placement

Shahriar MAHBUB[1], Nusrat SHARMIN[2]
Department of Computer Science
"Lucian Blaga" University of Sibiu
E. Cioran Str., No. 4, Sibiu - 550025, ROMANIA
[1]shahriar.mahbub, [2]nusrat.sharmin@ulbsibiu.ro

Abstract — **In the designing of a mobile phone network (cellular network) it is very important to place the base stations optimally for the cheaper and better customer service. As this is a NP-hard optimization problem so heuristic approach is a good choice. We propose a new evolutionary approach to solve base station transmitter location (BST-L) problem. The algorithm is designed to meet two main objectives. One is to cover all demands of the service area and another is minimizing the interference as much as possible. In our proposed approach, we use only mutation operator. To make the process efficient random and problem-specific knowledge is used in the operator.**

Index Terms — **BST-L problem, Cellular Systems, Evolutionary Algorithm, interference minimization, mutation**

I. INTRODUCTION

Cellular networks are one of the most rapidly growing networks in the world. The goal of the network design is to provide the maximum customer service with minimum cost (using minimum base station). The BST-L is a NP-hard [1] problem as the minimum set-cover problem can be reduced in polynomial time to the BST-L problem. Another objective is to minimize the interference which is also a very important parameter of cellular network design. Some heuristic approach has already used for BST-L problem [1-2].

Typical evolutionary algorithm has two operators to explore the search space. One is crossover and another is mutation. In BST-L problem, we think that crossover operator may make the solution unstable that why we chose to use only mutation operator. We use two different mutations. Random Mutation (RM) is used to explore the search space as much as possible and Guided Mutation (GM) is used to fine tune the solution in mature stage. We have used six RM and six GM in our approach.

In next section, we have formalized the problem. In section III we present the design criteria to fit our problem in Evolutionary Algorithm. We show some Experiments and results in section IV. We draw the conclusion and some future work in section V.

II. PROBLEM FORMULATION

Tele-traffic demand is define by Erlang. We consider a fixed sized geographical area on which some nodes are representing the tele-traffic demand in Erlang of a certain area. We call those nodes as demand node. Each demand node may have separate value that represents the different traffic demand of the service area. Our task is to place the minimum number of base stations in such a way so that they can cover all the demand nodes with minimum interference. Transmitters may be differing from one another in signal strength and capacity (number of channels), and direction of the antenna.

Now, we are presenting technical specification of the problem.

The geographic area is defined by A= {(Xmin, Ymin), (Xmax, Ymax)}.

Transmitter, $t \in T$, t = {(x,y), pow, r, cap, antenna_pattern }

- T is the set of finite possible transmitters.
- x, y is the position of the transmitter in the geographic area.
- pow means signal strength.
- Antenna_pattern means what is the pattern of the antenna (omni-directional or directional).

Demand node, $d \in D$, d= {(x,y), E}

- D is the finite set of possible node.
- E is tele-traffic load in Enlang.

A cellular network is made up of a number of cells each served by a fixed transmitter or base station. Since each cell is designed to use radio frequencies only within its boundaries, the same frequencies can be reused in other cells not far away with little potential for interference. The reuse of frequencies permits a cellular system to handle a huge number of calls with a limited number of channels. Those cell which are used the same frequency is called Co-Channel cells. And the interference among those Co-Channel cells is called Co-Channel interference [5]. In our problem, we only consider Co-Channel interference.

Signal-to-interference ratio (SIR) measure the received signal quality at the receiver. It is the ratio of the power of the wanted signal to the total residue power of the unwanted signals. We consider our network is designed in Advanced Mobile Phone System (AMPS) standard. In that case if the SIR is greater than 18 dB throughout most of the cell then it is thought that the network is properly designed.

Solution, S = $\{t_1,......,t_n \mid t_i \in T$ and all demand nodes are covered and SIR > 18 db for most of the cell$\}$

III. INSIDE THE EVOLUTIONARY ALGORITHM

A. INITIALIZATION

We use fully random initialization in order to initialize the individuals. Initially, no problem specific knowledge is given. It is very important to initialize the individuals randomly so that they can reach every possible area in search space. It ensures that the solution has a high probability that not to stack into local optima. The transmitters are placed anywhere within the geographical area. The other parameters of the transmitters are also randomly initialized.

B. Repair Function

As the placement of transmitters is totally random it is easily possible that some of the demand nodes are not yet covered by any of the transmitters that are randomly placed. So here we introduce a "Repair function" to cover those uncovered node.

```
Algorithm of Repair function:
For each node that is not covered
    1. Find nearest transmitter
    2. If possible Increase power and
       capacity to cover the node
    3. Else
        1. Find out all node within a
           range
        2. Sum up all demands of the
           node
        3. find Xmin, Xmax, Ymin, Ymax
        4. find number of transmitter
           required to cover all
           uncovered node within {
           (Xmin, Xmax), (Ymin, Ymax)}
        5. introduce those number of
           transmitters within {(Xmin,
           Xmax) , (Ymin, Ymax)} with
           random power and maximum
           capacity
```

C. Mutation

The goal of a solution of a problem is to reach the global optima. Sometimes it's very much possible that the solution of a problem is trapped into the local optima. So we introduce two kinds of mutation operator so that we can search every possible area of a search space.

In our Experiment two different types of mutation is used.

1. Random Mutation (RM) and
2. Guided Mutation (GM).

Random mutation is used so that the solution can explore every potential area of the search space. No problem specific knowledge is used in random mutation. And guided Mutation is used to exploit the problem specific knowledge to fine tune the solution. We use six Random and six Guided Mutation in our Experiment. First we'll going to introduce the random mutation.

- **RM1:**
  - Change the position of a randomly chosen transmitter within a specific limit.
- **RM2:**
  - Change the power (signal strength) of a randomly chosen transmitter within a limit.
- **RM3:**
  - Change the capacity (number of frequency) of a randomly selected transmitter.
- **RM4:**
  - Toggle the antenna pattern of randomly chosen transmitter (omni-direction to directional or directional to omni-directional).
- **RM5:**
  - Introduce a new transmitter in any position of that territory.
- **RM6:**
  - Delete a randomly chosen transmitter.

The Guided Mutations are:

- **GM1:**
  - **Precondition:** If there exists a transmitter with unused frequency channel.
  - **Action:** Allocate frequency according to the demand.
- **GM2:**
  - **Precondition:** If there exists a transmitter with all channel used.
  - **Action:** Introduce a new transmitter within a specific range with default configuration and reduce the power of the transmitter.
- **GM3:**
  - **Precondition:** If there exists a transmitter with SIR is less that 18 db and an omni-directional antenna is used.
  - **Action:** Change the antenna pattern to directional pattern.
- **GM4:**
  - **Precondition:** If there exist two transmitters with same frequency used that have not minimum distance between them.
  - **Action:** Change the position of a randomly selected transmitter within a specific limit.
- **GM5:**
  - **Precondition:** If there exists a transmitter that cover a very little demand.
  - **Action:** Remove the transmitter and increase the power of the surrounding transmitter so that they can cover that demand.
- **GM6:**
  - **Precondition:** If there exists a number of transmitters in the same position.
  - **Action:** Keep one transmitter and remove all other transmitters that are situated in the same place.

We have introduced an order to apply mutations. We use Random mutation in the premature stage of the evolution. When we think our solution reach in mature stage we just want to use Guided mutations to fine tune the solution (Figure 1). To make the order of applying Random mutation we concentrate on two things. We do not want that the individuals will be unstable after applying a mutation. For example, we do not apply mutation like RM6 (delete a randomly chosen transmitter) in the beginning of the order. We also keep in mind that each operator has a cost. So we apply operators based on cost in increasing order. In figure 1, it is shown that the cheapest operation is introduced last because it may make the individual unstable.

D. Fitness Function

In our problem, two objectives must be met.

a) The design must cover all the demand that means all the traffic demand.
b) Reduce co-channel interference as much as possible.

We introduce two different fitness functions for two objectives and global fitness function to the combination of two fitness functions. So, our global fitness function is:

$$\text{fitness of an individual} = \begin{pmatrix} \alpha * \text{Demand fitness} + \\ \beta * \text{co} - \text{channel int erence fitness} \end{pmatrix}^{\delta} / N$$

- α, β represents the weight of each individual objective fitness.
- N represents the number of base stations.
- δ is a factor that tuned among coverage, interference, channel allocation with respect to the number of transmitters.

```
Algorithm for Demand Fitness:
•  Calculate max power received by the
   each demand node
     o  If received power > threshold
        power
          ▪  Demand_node_fitness+=dema
             nd/total demand

Algorithm for Co-channel interference
Fitness
•  For each transmitter of individual
     o  x = calculate Signal-to-
        interference ratio
     o  if x is greater than 18db
          ▪  co_channel_interference_f
             itness+=(x-18)/18
     o  end if
•  end for
```

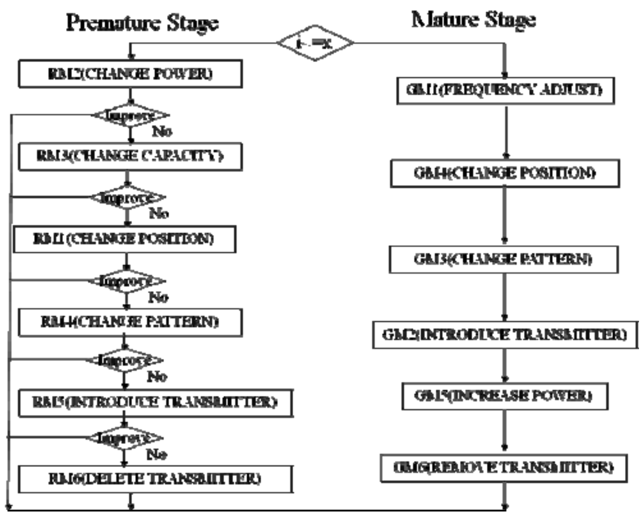

Figure 1 Mutation Order

E. The Stopping Criteria

If all the demand nodes are covered and 80% of the cells have SIR is greater than 18db then the iteration will stop.

IV. Experiments and Results

For the experiment we develop a very scalable simulator in C language. Here we work with five demand nodes; the simulator can be easily expanded to work with a significant number of demand nodes. The simulator can also adopt different kinds of environment by changing the parameter set. The simulator is able to stop after any number of iterations or it stops automatically when the predefined stopping criteria will meet.

We use synthetic data for our experiment because it's very difficult to get the real data from a telecom company. We simulate two different scenarios. We consider our geographical area can be maximum 12x12 Unit. In each scenario we have five demand nodes as input. For the same input, different outputs are obtained in polynomial time. The following table (TABLE 1) contains the input of the simulator. And TABLE 2 shows the result of the simulator.

We also develop a small module that can generate visual form of the result listed the above tables (TABLE 1 and TABLE 2). In the Figure 2 to Figure 7, the tiny dots indicate the location of a demand node and the circles denote the area covered by a particular transmitter.

TABLE 1. TWO SCENARIOS OF DEMAND NODES POSITION AND TELE-TRAFFIC LOAD

Scenario # 1			
Node #	X position	Y position	Tele traffic (Erlang)
1	5	7	7
2	6	9	20
3	1	0	10
4	7	7	6
5	8	8	12
Scenario # 2			
1	3	4	7
2	4	5	20
3	10	3	10
4	9	7	6
5	8	7	3

TABLE 2. DIFFERENT SOLUTIONS OF TWO SCENARIOS

Scenario # 1				
Solution Number	Number of Transmitters	X position	Y position	Radius
1	3	1	0	0.09
		5	8	1.53
		8	8	1.53
2	3	7	7	1.53
		6	8	1.53
		1	0	1.53
3	4	4	7	1.01
		1	0	0.59
		6	9	1.53
		7	7	1.53
1	3	10	3	0.83
		8	7	1.01
		4	5	1.53
2	3	10	3	0.30
		8	7	1.33
		3	4	1.53
3	4	11	4	1.43
		8	7	1.09
		3	4	0.30
		4	5	1.53

It is observed from the result that we may do not get optimum result but we get considerably good result with our evolutionary approach.

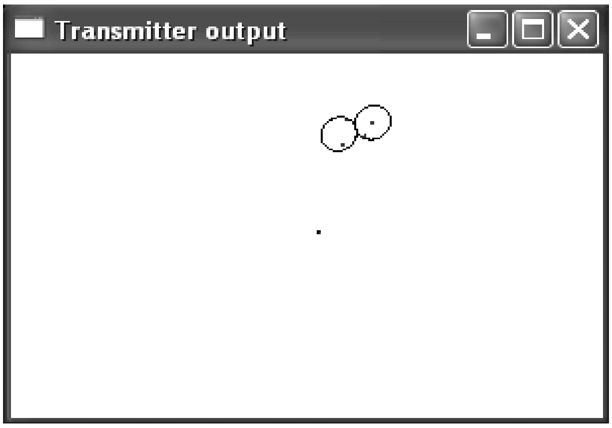

Figure 2 Visual view of Scenario# 1, Solution # 1

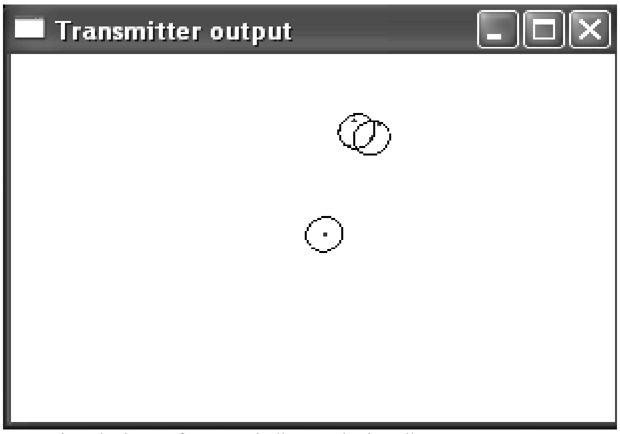

Figure 3 Visual view of Scenario# 1, Solution # 2

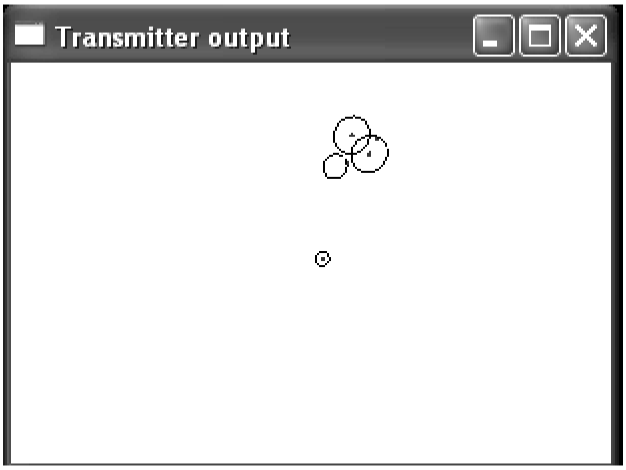

Figure 4 Visual view of Scenario# 1, Solution # 3

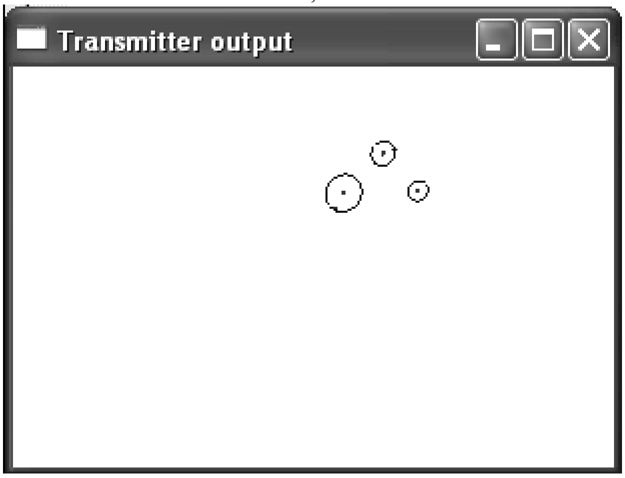

Figure 5 Visual view of Scenario# 2, Solution # 1

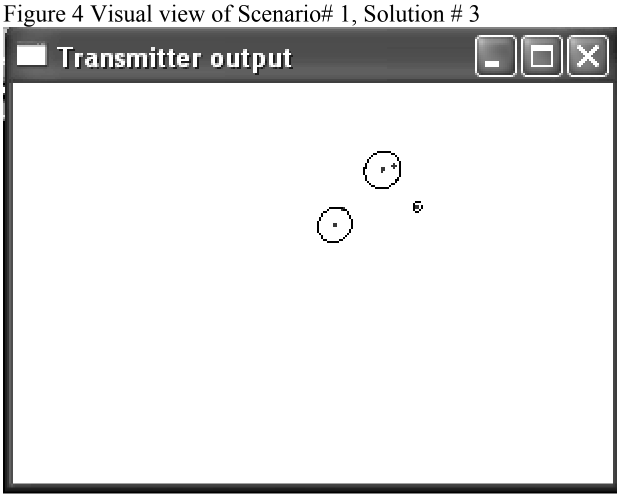

Figure 6 Visual view of Scenario# 2, Solution # 2

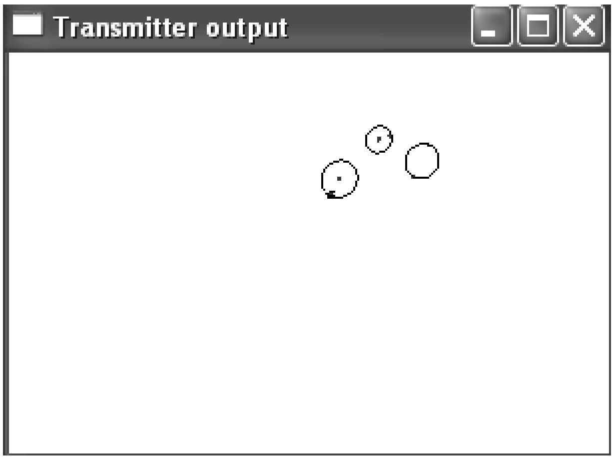

Figure 7 Visual view of Scenario# 2, Solution # 3

V. CONCLUSION AND FUTURE WORK

We already know that Evolutionary Algorithm have a good success on NP-hard problems. In this paper, we try to demonstrate the effect of the algorithm on base station placement problem. The result is good according to our synthetic data. Our future plan is to test our approach in real world data. We want to analysis the effect of crossover operator in this problem. Development of more problem specific operators and test them is also within our future plan.

REFERENCES

[1] Nicole Weicker, Gabor Szabo, Karsten Weicker, and Peter Widmayer, "Evolutionary Multiobjective Optimization for Base Station Transmitter Placement with Frequency Assignment", IEEE TRANSACTIONS ON EVOLUTIONARY COMPUTATION, VOL. 7, NO. 2, APRIL 2003.

[2] Geetali Vidyarthi, Alioune Ngom, and Ivan Stojmenovi´c, "Combinatorial Evolutionary Methods in Wireless Mobile Computing", Kluwer Academic Publishers, 2005.

[3] Kurt Tutschku, Rudolf Mathar, and Thomas Niessen, "Interference Minimization in Wireless Communication Systems by Optimal Cell Site Selection", 3rd European Personal Mobile Communication Cenferrence, MARCH 1999.

[4] Larry Raisanen_, Roger M. Whitaker, and Steve Hurley, "A comparison of randomized and evolutionary approaches for optimizing base station site selection", Proceedings of the 2004 ACM symposium on Applied computing, PP. 1159 – 1161, 2004.

[5] K. Tutschku, T. Leskien, and P. Tran-Gia, "Traffic estimation and characterization for the design of mobile communication networks, " Univ. of Würzburg, Würzburg, Germany, Tech. Rep. 171, ser. Inst. of Comput. Sci. Res. Rep. Series, 1997.

[6] Mischa Schwartz, Mobile Wireless Communications. Cambridge University Press, 2005.

[7] T Back, Evolutionary Algorithms in Theory and Practice. Oxford University Press, New York, 1996