

# A Heuristic Method of Cell to Switch Assignment in Mobile Communication Networks Using Firefly Algorithm

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**Abstract**--This paper deals with a design problem for a network of Mobile Communication Services (MCN). The goal is to assign cells to switches in a MCS Network in an efficient manner .It is a NP-Hard problem. We consider three types of costs. One is the cost of handoff between cells. The other is the cost of cabling or trunking between a cell and its associated switch. The third cost is switching cost which includes the cost for transferring a call to other switch. The problem is constrained by the capacity of switch and assignment of a cell to a unique switch. Firefly algorithm is implemented in this paper along with heuristics method to solve the problem of assignment of cells to switches and results are compared with that of Particle Swarm Optimization and Firefly Algorithm.

**Index Terms**-- Cell to switch assignment, Firefly algorithm, Heuristics, MCS, Particle swarm optimization, Optimization.

## 1. INTRODUCTION

Since the last decades, there have been significant advances in the development of mobile communication systems.

Now a day the mobile networks are migrating towards broadband services based on high speed wireless access technologies [1]. Even though significant improvement to communication infrastructure has been aimed in the mobile industry, the issues concerning the assignment of cells to switches in order to minimize the cabling cost, handoff cost and switching cost in a reasonable time still remain challenging. The same problem is addressed in this paper. Our motive is to minimize three costs namely: cabling cost, handoff cost and switching cost. Cabling cost involves the consumption of resources while maintaining communication link between two users [2].

The handoff caused by a subscriber movement from one cell to another, involves not only the modification of the location of the subscriber in the database but also the

between cell A and cell B is less because it involves only Switch1 and also the handoff is simple while handoff between cell A and cell C is complex and the handoff cost is also more as it involves two switches i.e. Switch1 and Switch2 Therefore, there are two types of handoffs, one involves only one switch and the other involves two switches. Intuitively, the cells among which the handoff frequency is high should be assigned to the same switch as far as possible to reduce the cost of handoffs. Merchant [3] gave a comprehensive description about handoffs. Switching cost occurs when two user which are communicating belong to different MSCs. However, since the call handling capacity of each switch is limited, this should be taken as a constraint. Incorporating the cabling cost, handoff cost and switching cost that occurs when a call is connected between a cell and a switch, we have an optimization problem[4], called the cell to switch assignment problem.

This paper presents idea to solve the problem of assignment of cells to switches using Firefly Algorithm given In 2008,byXin-She Yang [5] along with Heuristics method used by Bhaskar Sen Gupta in 1995 [3]. In next section the mathematical formulation has been done for this problem. In the next section it is shown how firefly algorithm and Heuristic method can be implemented for this problem.

## 2. PROBLEM FORMULATION

The problem of assignment of cells to switches was first introduced by Arif Merchant and Bhaskar Sengupta [3] in 1995. The assignment of cell to the switches is an NP-Hard

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- execution of a fairly complicated protocol between switches Switch1 and Switch2 as shown in fig.1.The handoff cost

problem, having an exponential complexity (n cells and m switches). He introduced two types of costs namely handoff cost and cabling cost. He also proposed a heuristic method to solve this problem. Now in this paper another cost called Switching cost [6] is introduced which is the cost for transferring a call form one switch to another. Thus in this paper we have an optimization problem for minimizing the above costs which is stated as follows:

Assign all the cells in a geographical area to the available number of switches in order to minimize the total cost which is the sum of cabling cost, handoff cost and switching cost maintaining the following two constraints.

- 1) Each cell must be assigned to exactly one switch and
- 2) Each switch has some limited capacity and assignment of cells must be done in such a way so that the total load on the switch should not exceed the capacity of the switch.

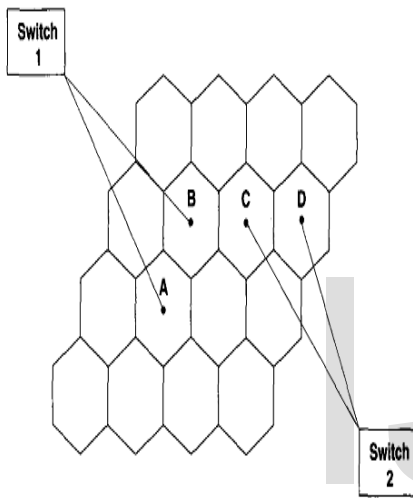


Fig1. Handoff from B to C is more expansive than B to A.

### 3. MATHEMATICAL MODELING

The assignment of cell to the switches is an NP-Hard problem, having an exponential complexity (n cells and m switches) [6].

- Let no. of cells be 'n' and no. of switches be 'm'
- $h_{ij}$  – handoff cost between cell i and cell j
- $c_{ik}$  – cabling cost between cell i and switch k
- $d_{ij}$  – distance between cell i and switch (MSC) j
- $M_k$  – call handling capacity of switch k
- $\lambda_i$  – No of communication in cell i
- $Y_{ij}$  – 1 if cell I and j are assigned to same switch and 0 otherwise.
- $X_{ik}$  – 1 if cell I is assigned to switch k and 0 otherwise.

#### 3.1 FORMULATION OF CONSTRAINTS:

- 1) Each cell must be assigned to exactly one switch

$$\sum_{k=1}^m x_{ik} = 1, \quad 1 \leq i \leq n \quad \dots (1)$$

- 2) Each switch has some capacity

$$\sum_{i=1}^n \lambda_i x_{ik} \leq M_k, \quad 1 \leq k \leq m \quad \dots (2)$$

#### 3.2 FORMULATION OF COST FUNCTION:

- 1) **Total Cabling Cost:** this is formulated as a function of distance between base station and switch and number of calls that a cell can handle per unit time [8].  $c_{ij}(\lambda_j)$  is the cost of

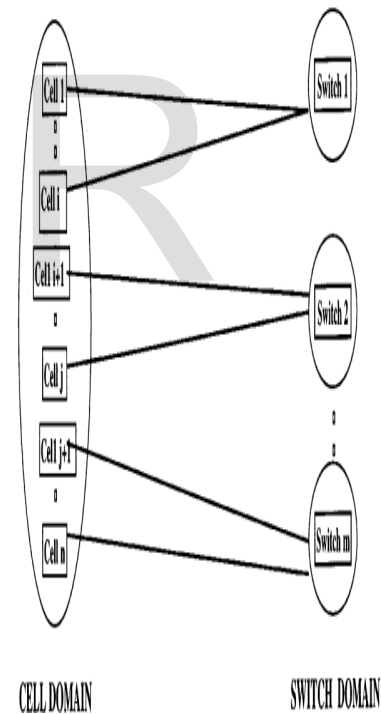


Fig 2: Mapping representation for CSA problem[7]

cabling per kilometre which is also modelled as a function of the number of calls that a cell can i handles as:

$$c_{ij} = A_{ij} + B_{ij}\lambda_j \quad \dots (3)$$

$$\sum_{j=1}^m c_{ij}(\lambda_j) d_{ij} x_{ij} \quad \text{for } i = 1, 2, \dots, n \quad \dots (4)$$

- 2) **Total handoff cost:** we consider two types of handoffs, one which involves only one switch and another which involves two switches. The handoff that occurs between cells that belong to the same switch consume much less network resources than what occurs between cells that belongs to two different switches.

$$\sum_{i=1}^n \sum_{j=1}^n h_{ij} (1 - y_{ij}) \quad \dots (5)$$

- 3) **Total Switching Cost:** let  $\beta_i$  is the total no of calls MSC  $i$  can handle per unit time and  $F_i(\beta_i)$  is the cost function of switching a call in MSC  $i$ . Thus the load at MSC is given by:

$$\beta_i = \sum_{j=1}^n \lambda_j x_{ji}, \quad \text{for all } i = 1 \dots m \quad \dots (6)$$

$F_i(\beta_i)$  involves both the cost of switching and the cost of maintaining a call at MSC. Thus  $F_i(\beta_i)$  can be represented as:

$$F_i(\beta_i) = \alpha / (\mu_i - \beta_i) \quad \beta_i < \mu_i \quad \dots (7)$$

Where  $\mu_i$  denote the call switching capacity of MSC  $i$  and  $\alpha$  is a constant.

The total switching cost involved is defined by:

$$\sum_{i=1}^m \beta_i F_i(\beta_i) \quad \dots (8)$$

**Total Cost:** So our objective is to minimize the total cost which can be formed by the summation of all three costs. The objective function is given by:

$$\sum_{j=1}^m c_{ij}(\lambda_j) d_{ij} x_{ij} + \sum_{i=1}^n \sum_{j=1}^n h_{ij} (1 - y_{ij}) + \sum_{i=1}^m \beta_i F_i(\beta_i) \quad \dots (9)$$

#### 4. EXISTING METHODOLOGY

Assigning cells to switches in cellular mobile network being an NP-hard problem and enumerative search methods are not appropriate to solve large sized instances of this problem. There are various methods available for assigning cell to switches like, heuristic approaches, like Genetic Algorithm [4] [9], Ant Colony Optimization [10] and Particle Swarm Optimization [11] have been developed for this kind of problem. All these algorithms considered only cabling cost and handoff cost except [6] and [12].

In this paper Firefly Algorithm [5] along with the Heuristic Method [3] is implemented and results are compared with Firefly Algorithm alone as used in [12] and with the Particle Swarm Optimization as used in [11].

#### 5. IMPLEMENTATION OF FIREFLY ALGORITHM ALONG WITH HEURISTIC METHOD

##### 5.1 FIREFLY ALGORITHM

Firefly algorithm is developed by Xin-She Yang [5] in 2008 which is inspired by the mutual attraction of fireflies based on the absorption of light and distance between two fireflies. Algorithm considers that each firefly has fixed position in the space and it always move towards a greater light source, then is his own.

Firefly algorithm idealizes some of the characteristics of the firefly behavior. They follow three rules:

- 1) All the fireflies are unisex,
- 2) Each firefly is attracted only to the fireflies, that are brighter than itself; strength of the attractiveness is proportional to the firefly's brightness, which attenuates over the distance; the brightest firefly moves randomly and,
- 3) Brightness of every firefly determines its quality of solution; in most of the cases, it can be proportional to the objective function.

##### 5.2 HEURISTIC METHOD

Heuristic Method is used to find out the best initial solution as given in [3] and we assign this best solution to one firefly and all other  $p-1$  fireflies are assigned random values.

### 5.3 ALGORITHM

The steps for implementation of algorithm are as follows:

#### Step 1

- Initialize the number of cells ( $n$ ), switches ( $m$ ) and number of fireflies ( $p$ ) in the solution space.
- Initialize  $p-1$  fireflies randomly and assign the initial best solution to one firefly as obtained by the Heuristic Method.
- Initialize position of cells and switches randomly in the search space.
- Calculate distance between each cell and switch.

#### Step 2

- Generate the assigned matrix ( $x_{ij}$ ) for each firefly where each particle is between 0 and 1.
- The row of the matrix represents switches and column represents cells.

#### Step 3

- Obtain solution matrix from the assigned matrix by making the largest value of each column to 1 and all other are set to 0.

#### Step 4

- Calculate the total cost based on this solution matrix.

#### Step 5

- On the basis of this new cost the brightest firefly is found which has the minimum cost for the assignment.
- Now update the position of all other fireflies based on the attractiveness of best firefly and also on the basis of distance and randomness of fireflies.
- Now update the position of best firefly randomly.
- Repeat step 3 to 5 until stopping criterion is met.

## 6. EXPERIMENTS AND RESULTS

To test the effectiveness of Firefly Algorithm for the cell assignment problem, we design and conduct a series of experiments. All the experiments are done using a MATLAB code for various cases of cells and switches for firefly algorithm. Regarding the test problems, we assume that the cells lie on a hexagonal grid of roughly equal dimensions in 2 dimensions. The parameters used for firefly algorithm are number of cells ( $n$ ), number of switches ( $m$ ) and number of fireflies ( $p$ ).

Values of constants used are as follows:

- Randomness,  $\alpha=1$
- Absorption coefficient,  $\beta=1$
- Brightness at source=1

The parameters used in the initialization of problem are:

- handoff cost between two cells= 0 to 14 per hour
- constant A used in cabling cost=1
- constant B used in cabling cost=0.001
- call handling capacity of a switch=98000
- constant  $\alpha$  used in switching cost=40
- number of communication in a cell=0 to 200 per hour

### 6.1 COST TABLE

Switches, Cells	Total Cost (Firefly + Heuristic Method)	Total Cost (Firefly)	Total Cost (PSO)
2, 25	1902	1915	1936
2, 50	7806	7894	7954
2, 100	33312	33414	33528
2, 150	78109	78213	78279
2, 200	133998	134200	134280
2, 250	216366	216370	216410
3, 25	2405	2417	2478
3, 50	10806	10973	11022
3, 100	45169	45208	45290
3, 150	102165	102230	102310
3, 200	181788	181870	181920
3, 250	288010	288090	288160

5, 25	2876	2979	3011
5, 50	13576	13642	13735
5, 100	54296	54395	54481
5, 150	124765	124880	124940
5, 200	220005	220030	220160
5, 250	344000	344020	344180
10, 25	3675	3711	3800
10, 50	15165	15273	15411
10, 100	61564	61999	62158
10, 150	137958	138280	139020
10, 200	248643	248710	249360
10, 250	390063	390140	391420

## 6.2 ANALYSIS OF RESULT

Motion of fireflies is best for the above values of  $\alpha$ ,  $\beta$  and  $\gamma$ . For lesser values of these parameters the change in the assignment is very low. As the number of cells and switches is increased the final cost value also increased and with these large problem instances it is taking more number of iterations and more time. We have conducted experiments to find the minimum total cost by repeating the experiments for 5, 10, 15 times for each set of parameters. These experiments reveals that the optimum cost obtained in each execution is always nearer to the average cost.

Table 6.1 shows the minimized cost for different cases of cells and switches. It also compare the minimized cost by the three algorithms: Firefly along with Heuristics Method, Firefly and PSO and from this list we can see that comparatively lesser cost is found using Firefly along with Heuristics Method and so it is better in terms of finding minimum cost. Form experiments it is noted that the total minimized cost can be reduced with larger number of iterations and also with larger number of fireflies.

## 7. CONCLUSION

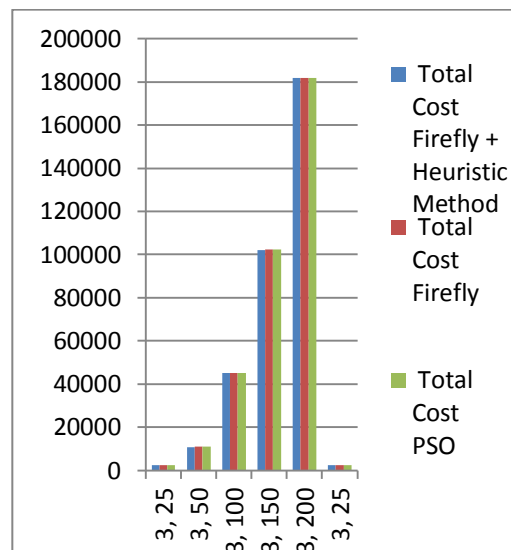
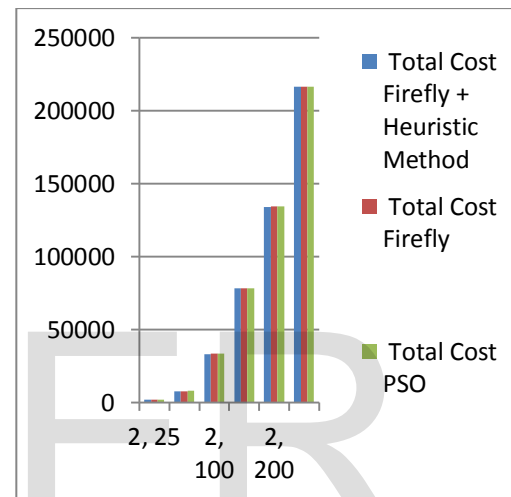
From the experiments performed we can conclude that firefly algorithm along with Heuristics Method can be implemented successfully for the assignment of cells to the switches. The following conclusions can be drawn:

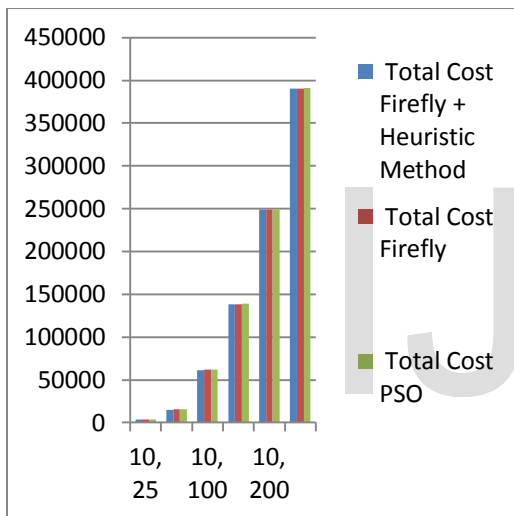
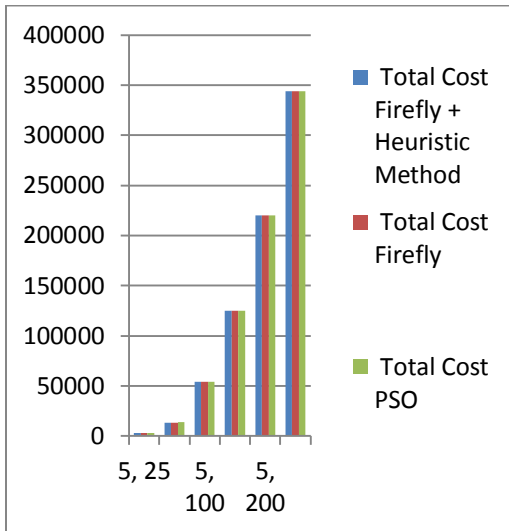
1. As the number of fireflies is increased the probability of finding the minimum cost and in less number of

iterations is increased. The CPU time requirement is less in case of firefly algorithm as compared to PSO.

2. As the number of fireflies is increased in the solution space the probability of convergence to the global minima in comparatively lesser number of iterations is increased. But this will increase the complexity in the execution and CPU time requirement.

## COST COMPARISON GRAPHS





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