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A Native Approach to Cell to Switch Assignment Using Firefly Algorithm

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Abstract—This paper deals with a design problem for a network of Personal Communication Services (PCS). The goal is to assign cells to switches in a PCS Network (PCSN) in an optimum manner so as to minimize the total cost which includes two types of cost, namely handoff cost between two adjacent cells, and cable cost between cells and switches. The problem of assigning cells to switches in a cellular mobile network is an NP-hard optimization problem. The design is to be optimized subject to the constraint that the call volume of each switch must not exceed its call handling capacity. However, because of the time complexity of the problem, the solution procedures are usually heuristic when the number of cells and switches are more. In this paper we have proposed an assignment heuristic which is faster than the existing algorithms. This paper describes Firefly Algorithm and proposes a possible way it can be adjusted to solve the problem of assignment of cells of a geographical area to the available number of switches based on the minimization of total cost for the assignment.

Keywords—PCS, cell to switch assignment, handoff, optimization, heuristics and combinatorial optimisation, PSO, FA.

I. INTRODUCTION

In 2008, Xin-She Yang [1] introduced a new Meta - heuristics algorithm Firefly Algorithm that is inspired by firefly's social behaviour. In the basic form, this algorithm is designed to solve primarily continuous problems. The aim of this work is to get an assignment of cells in a geographical area to the available switches so that the total cost of this assignment is minimized. Since the last couple of decades, there have been significant advances in the development of mobile communication systems. Even though significant improvement to communication infrastructure has been attained in the personal communication service industry, the issues concerning the assignment of cells to switches in order to minimize the cabling cost and handoff costs in a reasonable time still remain challenging [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 execution of a fairly complicated protocol between switches S1 and S2 [3]. Therefore, there are two types of handoffs, one involves only one switch and the other involves two switches. The latter is relatively more difficult and costly than the former. 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. However, since the call handling capacity of each switch is limited, this should be taken as a constraint. Incorporating the cabling cost that occurs when a call is connected between a cell and a switch, we have an optimization problem, called the cell assignment problem [4], of assigning cells to switches such that the total cost, comprising of handoff cost between adjacent cells and cabling cost between cells and switches, is minimized subject to the constraints of the call handling capacities of switches.
Here two algorithms are used to find this assignment:

1) PSO Algorithm
2) Firefly Algorithm

II. CELL ASSIGNMENT PROBLEM

In this section, the problem formulation and the mathematical modelling is discussed.

2.1 Problem Formulation

The assignment of cells to switches is first introduced by Arif Merchant and Bhaskar Sengupta [5] in 1995. This problem is an NP-Complete problem. Based on these ideas presented above this paper presents the problem as:
"Assign all the cells in a particular geographical area to the available number of switches in order to minimize the total cost which is the sum of cabling cost and handoff cost maintaining two constraints."
The constraints for the problem are as follows:

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

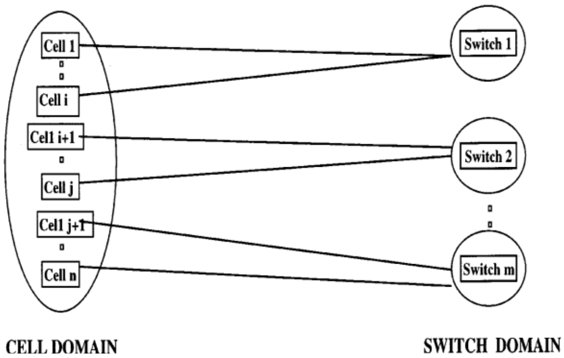


Fig 1: mapping representation for CSA problem [6]

III. MATHEMATICAL MODELLING

The assignment of cell to the switches is an NP-Hard problem, having an exponential complexity (n cells and m switches) [2].

- 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
- λi - 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.

For all cases, the range of i, j and k are defined as:

$$1 \leq i \leq n, 1 \leq j \leq n, 1 \leq k \leq m$$

3.1 Formulation of constraints:

1) Each cell must be assigned to exactly one switch

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

2) Each switch has some capacity

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

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 [7]. $c_{ij}\,(\lambda_j)$ is the cost of cabling per kilometre which is also modelled as a function of the number of calls that a cell i can handle as:

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

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

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.

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

3) 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:

$$\sum_{j=1}^{m} c_{ij}(\lambda_j)d_{ij}x_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{n} h_{ij}(1-y_{ij}) \ldots (6)$$

IV. EXISTING METHODOLOGY

There are various methods available for assigning cell to switches but this problem gets complicated for large size hence heuristics are needed to solve this problem. In this paper Firefly algorithm is proposed and the results are compared with PSO.

4.1 Particle Swarm Optimisation

PSO method consists of a collection (called swarm) of individual entities (called particles). Each particle represents a solution in the solution space and iteratively evaluates the fitness of the candidate solutions and remembers the location where they had their best success. The individual's best solution is called the local best (lbest). Each particle makes this information available to other particles and could learn the global best solution (gbest). [8].

- A global best (gbest) is known to all and immediately updated when a new best position is found by any particle in the swarm.
- The local best (lbest), which is the best solution that the particle has seen.

Based on these gbest and lbest values the velocity and the position of each particle is updated. The particle position and velocity update equations in the simplest form that govern the PSO are given by [8].

$$V_{t+1} = c_1V_t + c_2r_1(lbest - x_t) + c_3r_2(gbest - x_t) \qquad \ldots (7)$$

$$x_{t+1} = x_t + V_{t+1} \qquad \ldots (8)$$

where, c1, c2, c3 are the constant weight vector for the previous velocity, local knowledge and global knowledge respectively and r1 and r2 are two random variables in the range of 0 and 1 [2]. The selection of coefficients in the velocity update equations affects the convergence and the ability of the swarm to find the optimum.

4.2 PSO Algorithm [2]

Step 1:

- Initialize the objective function which is to be minimized and various user defined constants.
- Initialize the number of particles.
- Set the output or position of maximum or minimum in the objective function.

Step 2: Initialize all the particles and there corresponding positions or solution in the solution space.
Step 3: Find the best particles which has the minimum solution (for minima problems) or maximum solution (for maxima problems). The solution of this particle is called global best (gbest).
Step 4: For each element find the local best solution which is the minimum solution up to that iteration. This local best solution for each particle is called lbest.
Step 5: Now using lbest and gbest update the velocity of each particle using equation (7) and then update the position of each particle using equation (8).
Step 6: Repeat steps 3 to 5 until stopping criterion met.

V. FIREFLY ALGORITHM

In this section the actual implementation of firefly algorithm for cell to switch assignment problem is explained [9]. As discussed above that each firefly in the solution space is a complete solution which is independent to the other fireflies. Implementation of firefly algorithm starts with spreading a particular number of fireflies in the solution space. The initial position of fireflies may be random or fixed as given by the user. The initial solution means the initial assignment matrix for each firefly and correspondingly the cost for that assignment [10]. Now each firefly in the solution space has an assignment and corresponding cost for that assignment. Based on this cost the firefly with minimum cost is selected as the brightest firefly and all the other fireflies move towards this brightest firefly depending upon randomness of firefly, distance between fireflies and absorption coefficient of fireflies. This is called motion update for firefly. In the cell assignment problem motion update means update the elements of assignment matrix. Thus the assignment matrix of each firefly is updated according to the cost of each firefly.

Now for this new assignment again total cost is calculated for each firefly and all the parameters like brightest firefly and update value for each assigned matrix are updated and this process is repeated until a stopping criterion is met [11]. From all the cost values of each firefly the one which is minimum of all is selected as the best value and the corresponding assignment is selected as the best assignment for the cells.

5.1 Implementation Details

The steps for implementation of firefly are as follows:

Step 1

- Initialize the number of cells (n), switches (m) and number of fireflies (p) in the solution space.
- 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.

VI. EXPERIMENTAL RESULTS AND ANALYSIS

All the experiments are done in MATLAB for various cases of cells and switches for two algorithms namely firefly algorithm (FA) and Particle Swarm Optimization (PSO). The various parameters used for firefly algorithm are as follows:

Randomness, α=1, absorption coefficient, γ=1, brightness at source=1.

The parameters used in the initialization of problem are: Handoff cost between two cells= 0 to 5,000 per hour, constant A and B used in cabling cost=1 and0.001 respectively, call handling capacity of a switch=98000, number of communication in a cell=500 to 1000 per hour.

The comparison of total cost and CPU time is shown below in graphs.

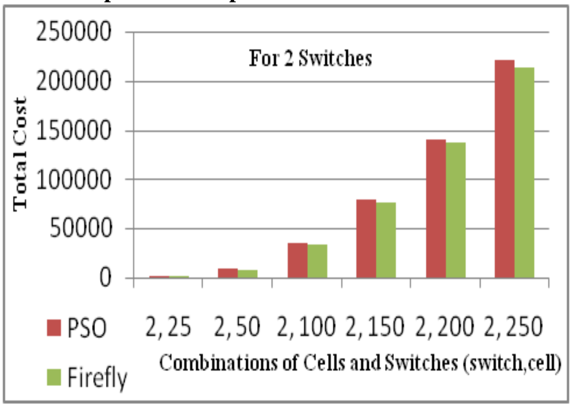
Table 1 **Comparison Table**

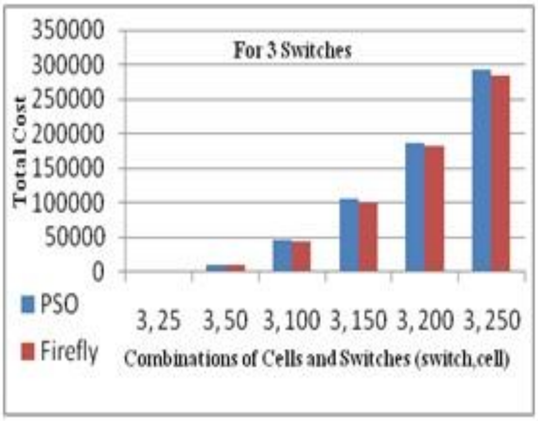
Switches, cells	Cabling cost	Handoff cost	Total cost by FA	Total cost by PSO	CPU Time FA	CPU Time PSO
2, 25	116	1919	2036	2177	0.175	0.2655
2, 50	316	7723	8040	9070	0.1996	0.2843
2, 100	496	32840	33337	35339	0.2766	0.3472
2, 150	851	75953	76804	79461	0.3929	0.4456
2, 200	1277	135630	136910	140670	0.5763	0.67
2, 250	1440	212390	213530	2201330	0.7713	0.9318
3, 25	153	2317	2470	2989	0.1723	0.2644
3, 50	361	10728	11095	11436	0.1701	0.2579
3, 100	591	43593	44185	46553	0.2635	0.3231
3, 150	693	98487	99180	105210	1.0216	1.185
3, 200	977	181380	182360	187100	1.786	1.7541
3, 250	1536	281720	283260	291850	2.2914	2.5471
5, 25	144	2945	3089	3710	0.2138	0.2783
5, 50	337	12673	13010	13936	0.3079	0.3817
5, 100	507	54483	54990	56452	0.5929	0.633
5, 150	990	122020	123010	126100	1.1268	1.158
5, 200	964	219390	220360	224530	1.5611	1.5302
5, 250	1460	347340	348800	352100	2.3752	2.5678
10, 25	135	3493	3623	3980	0.2244	0.286
10, 50	346	14881	15227	15538	0.3364	0.38
10, 100	515	61153	61668	62940	0.66	0.7132
10, 150	837	140070	140910	142990	1.1328	1.1871
10, 200	1163	246800	247970	253440	1.9344	1.9383
10, 250	1535	391560	393100	394120	2.5006	2.5572

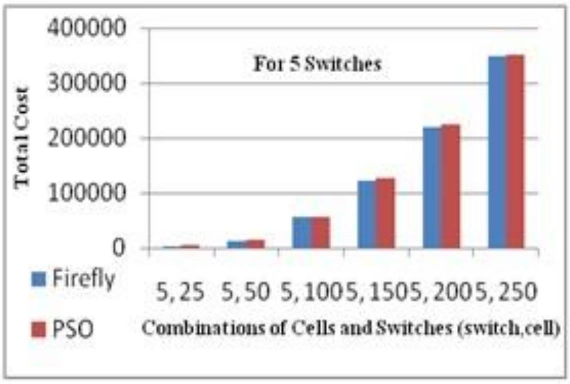
VII. CONCLUSION AND FUTURE WORK

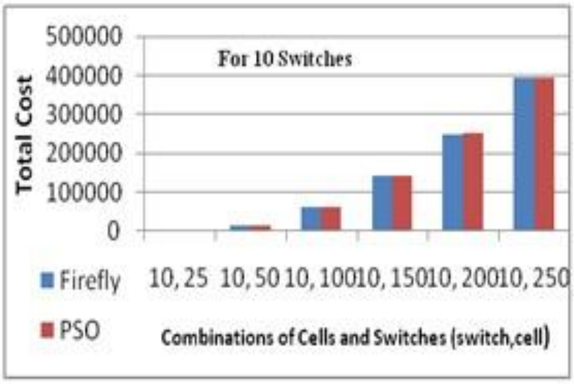
The Firefly Algorithm is successfully implemented. From the figures (a-d) and (e-h) we can see that the cost in two algorithms is comparable but the CPU time requirement in case of firefly is less as in case of PSO. As the iterations are increased the probability of finding the lowest cost increases. But this will also increase the CPU time spent in finding this minimum cost. The CPU time required for finding the minimum cost is comparatively less in Firefly algorithm as compared to PSO. Thus Firefly gives better performance when the execution time is concerned. In future, this work can be extended to include switching and paging cost to the total cost for cell to switch assignment.

Cost Comparison Graphs:



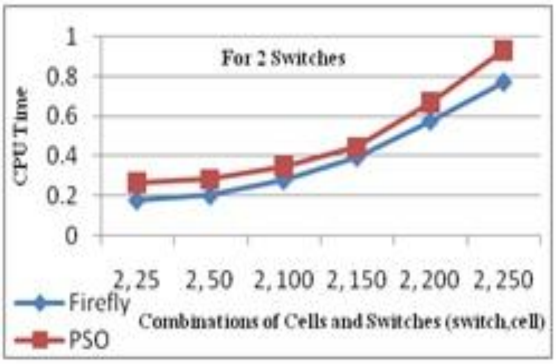


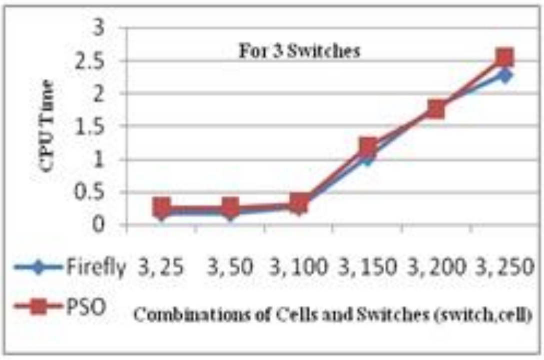


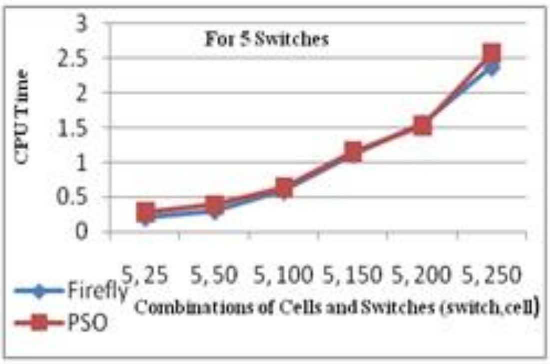


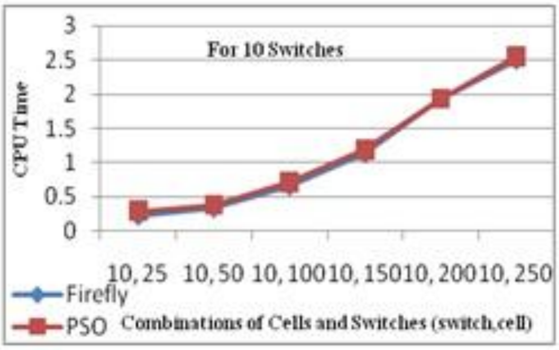
The above graphs shows the cost comparison for the proposed Firefly Algorithm and PSO.

CPU Time Comparison Graphs:









The above graphs show the CPU Time comparison graphs for proposed Firefly Algorithm and PSO.

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