Maximization Of Coverage Of The Base Station Antenna Using Pso Algorithm

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Abstract:

In this paper, Seamless connectivity with maximum coverage for a cellular organization is achieved through the implementation of the base station antenna on ideal locations which would increase the coverage. The number of base station antennas needed for achieving maximum coverage is determined by the traffic demand and its ideal locations are identified using PSO algorithm. Various parameters of cellular base station (BS) placement such as site coordinates, transmitting power, height and tilt angle are determined using PSO algorithm to obtain better compromised solutions. The maximization of service coverage and minimization of cost are considered as conflicting objectives.

Keywords- base station; PSO algorithm; coverage; RF planning; power

1. Introduction

Every cellular organization desires to achieve the seamless connectivity and maximum coverage through the effective implementation of frequency reuse, optimum cell layout, controlling of interferences and proper BS placement [11]. During the commissioning of BS in the desired area, design parameters like transmission power, height, azimuth, and tilt angle and path loss are usually taken into account. The non-adjustable constraints like traffic demand, overlap and handover are also considered for determining the coverage in global system for mobile communication (GSM) network [6]. In general, maximum cell coverage with minimum number of BS is a Nondeterministic Polynomial time NP-hard problem [2].

Researchers have applied various methodologies to find the optimum location of BS in the cellular network planning. Integrated cellular network planning tool (ICEPT) proposed by Tutschuka et al. [14] considered four types of major design aspects namely mobile subscriber, radio transmission, resource allocation and system architecture. Antony proposed [13] cost and time efficiency, radio wave coverage and planning tool (RAWCAPT) for its radio path planning using Lidar datasets. Caminada et al. [4] introduced Oasys automatic cell planning tool to determine optimum parameters like transmitted power, tilt and azimuth.

Previous methods have applied algorithms such as heuristic, meta-heuristics [simulated annealing (SA), Tabu search, genetic algorithm (GA)] and Greedy for BS placement. Meta-heuristic algorithm based on SA [2, 5, 9, and 7] and Tabu search [15] produced local optimum results from initial neighborhood set of solutions. The application of GA in cell planning [2, 6, 3, 10, 16, and 18] has produced significant results from the initial identified location coordinates.

Different types of network planning models have been proposed by various researchers. Rawnsley and Hurley [12] suggested network planning model with two phases namely placement of BS with configuration and frequency assignment. This model produced better result when compared with frequency assignment model which utilizes hill-climbing based search algorithm. Allen et al. [1] compared the performance of the automated cellular net-work planning with the manual planning in broadband wireless fixed network. Zimmerman et al. [18] recommended an advanced model of cell planning using hexagonal structure, path-loss propagation, antenna diagram losses, handover and traffic demand. Augmented objectives function is formulated by combining three quality objectives with traffic and coverage constraints. The model also employed three phase strategy namely initialization, repair and optimization to produce optimal solution.
Whitaker and Hurley [17] demonstrated new graph theoretical model to derive improved lower bounds on the minimum number of sites with coverage, traffic and interference as objectives using back tracking routine. Whitaker et al. [17] have investigated the macro-cell network planning from an infrastructure cost-centric perspective, by addressing the relation between infrastructure costs and coverage for a range of cell densities. Recently, Raisanen has introduced a permutation-coded multi objective evolutionary approach with three objectives: coverage, traffic hold and handover. Two types of coded strategies namely binary and permutation have been evaluated with NSGA-II. However, the epistatic relations between design parameters and objectives have not been considered. As only site coordinates (x, y) have been taken for optimization using PSO, there is no guarantee for global optimum result. Lakshmi Narasimman et al [8] have used NSGA algorithm for the mobile antenna placement. Nondominated solutions are derived to maximize the service coverage.

The ideal locations of base station antenna where maximum coverage can be achieved are identified using PSO algorithm. In this paper, all the parameters of Base Station such as site coordinates (x, y), transmitting power, and antenna height and antenna tilt angle are optimized using PSO algorithm. The proposed approach identifies the locations and parameter values by considering maximization of service coverage and minimization of cost as conflicting objectives in hexagonal geographical area.

The organization of the paper is as follows. Section II discusses the Base Station placement model and enumerates the objectives of BS placement model. An overview of PSO algorithm is detailed in Section III. Section IV focuses on the implementations of PSO for base station antenna and section V discusses the simulation results. Section VI presents the conclusion.

2. BS Placement Model

The BS placement model used in this paper is based on [2, 11]. The BS model represents cell model, BS, antenna parameters and mobile station characteristics. The following section covers the various components in the BS model in detail.

2.1 Cell model

The area where the BS needs to be installed is conveniently discretized into smaller cells. In the discretized area, the following sets are identified for the purpose of simulation.

1. A set of receiving testing points (RTP) given by the (x, y) coordinates distributed in the whole area with equal distance in between each other.
2. A set of service testing point (STP) is selected from the pool of RTP based on the service threshold $S_q$ usually -90 dBm.
3. A set of traffic testing points (TTP) is identified from STP based on the traffic demand which is measured in Erlang. TTP always satisfies $S_q$. As per the hierarchy of testing points, TTP, STP, and RTP.

The installation of BS consists of cell tower with the desired antenna in the cell structure. Out of three recommended cell structure namely triangular, rectangular and hexagonal, hexagonal structure is implemented since it covers large area with no ambiguous region. The traffic handling capacity expressed in terms of Erlang. Based on the number of channels required by BS, maximum traffic handling capacity is fixed as given in Table 1.

<table>
<thead>
<tr>
<th>TRX</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPACITY</td>
<td>2.9</td>
<td>8.2</td>
<td>15</td>
<td>22</td>
<td>28</td>
<td>35.5</td>
<td>43</td>
<td>58</td>
</tr>
</tbody>
</table>

2.2 Mobile station

Mobile devices are classified based on the types of services and $S_q$. Normally, the range of $S_q$ for indoor mobile devices is from -65 to -75 dB and outdoor mobile devices are from -80 to -90 dB each mobile device has mobile gain $M_G$ and mobile loss $M_L$ which are measured in dB. The normal height of mobile stations $h_m$ above the sea level is taken as 2 m.

The identification of optimal locations for every BS consists of conflicting multiple objectives and nonlinear constraints. In this paper, the objectives considered are coverage and cost.

2.3 Coverage

A set of STP is identified from a pool of RTP based on the receiving signal strength $S_q$. If an RTP is said to be covered by a BS as well as termed as STP, it should have the FS above $S_q$. The aim is to achieve maximum
coverage by covering maximum RTP. At the same time, it is not possible by a BS to cover all RTP due to restrictions in traffic handling capacity. One can adopt suitable methods [2, 11] to implement restrictions in traffic handling during coverage calculations.

2.4 Cost

The role of an efficient algorithm is to select optimal location to maximize coverage which indirectly reduces the number of antennas and its associated cost. If coverage needs to be improved, it is an obvious choice to increase the number of antennas. The cost factor is directly proportional to the number of BS and its adopted transmitting power as shown in Table 2. The incurred cost of a cell plan is the total cost of all BS (represented by a value in between 1 and 2) with the utilization of minimum transmitting power other than zero.

<table>
<thead>
<tr>
<th>Transmitted power (Watts)</th>
<th>1,000</th>
<th>501</th>
<th>251</th>
<th>125</th>
<th>63</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>2</td>
<td>1.8</td>
<td>1.6</td>
<td>1.4</td>
<td>1.2</td>
</tr>
</tbody>
</table>

2.5 Traffic demand

According to the maximum traffic load handling capacity by a transmitter, one BS can handle up to 43 Erlang. This constraint should allow a TTP to be attached to another BS based on the $S_Q$ value. Normally, a mobile device which receives signals above $S_Q$ should only select the strongest signal. By this analogy, BS calculates maximum traffic capacity after analyzing the TTP based on the strongest signal. Minimum number of BS can be calculated satisfying the traffic demand.

$$\text{Minimum antennae required} = \sum \frac{\text{Traffic demand of TTP}}{43}$$

(1)

The selection probability of TTP is based on the distance calculations from the center of the area. The STP residing close to center has a brighter chance to be considered as TTP. The selection probability quotient value (SPQV) is calculated for each and every STP. The generation and comparison of random value with this quotient value assigns the traffic demand value for TTP. This method gives equal opportunity to all TTP despite its location in the covered area.

$$SPQV = \frac{\text{Distance between center of the area and STP}}{\text{Distance between center of the area and furthest STP}}$$

(2)

3. Particle Swarm Optimization

Particle swarm optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. PSO optimizes a problem by having a population of candidate solutions, here dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle’s position and velocity. The Particle Swarm Optimization algorithm is a biologically-inspired algorithm motivated by a social analogy. Sometimes it is related to the Evolutionary Computation (EC) techniques, basically with Genetic Algorithms (GA) and Evolutionary Strategies (ES), but there are significant differences with those techniques. The PSO algorithm is population-based: a set of potential solutions evolves to approach a convenient solution (or set of solutions) for a problem. Being an optimization method, the aim is finding the global optimum of a real-valued function (fitness function) defined in a given space (search space). The social metaphor that led to this algorithm can be summarized as follows: the individuals that are part of a society hold an opinion that is part of a “belief space” (the search space) shared by every possible individual. Individuals may modify this “opinion state” based on three factors:

- The knowledge of the environment (its fitness value)
- The individual’s previous history of states (its memory)
- The previous history of states of the individual’s neighbourhood

An individual’s neighborhood may be defined in several ways, configuring somehow the “social network” of the individual. Several neighborhood topologies exist (full, ring, star, etc.) depending on whether an individual interacts with all, some, or only one of the rest of the population. Following certain rules of interaction, the individuals in the population adapt their scheme of belief to the ones that are more successful among their social
network. Over the time, a culture arises, in which the individuals hold opinions that are closely related.

In the PSO algorithm each individual is called a “particle”, and is subject to a movement in a multidimensional space that represents the belief space. Particles have memory, thus retaining part of their previous state. There is no restriction for particles to share the same point in belief space, but in any case their individuality is preserved. Each particle’s movement is the composition of an initial random velocity and two randomly weighted influences: individuality, the tendency to return to the particle’s best previous position, and sociality, the tendency to move towards the neighborhood’s best previous position.

4. Implementation

4.1 Algorithm

- Initialize the position of particles. (x,y) coordinates are the positions and the particle size is 50
- Evaluate fitness value for each particle set using the objective function which considers cost and coverage.
- Evaluate p\textsubscript{best} and g\textsubscript{best}.
- Update the position and velocity.
- Repeat the above steps for fixed iterations.

The Velocity factor and position are calculated using the following formulae.

\[
v_{n+1} = v_n + c_1 \text{rand1}(\cdot) (p_{\text{best},n} - \text{CurrentPosition}_n) + c_2 \text{rand2}(\cdot) (g_{\text{best},n} - \text{CurrentPosition}_n)
\]

\(v_{n+1}\): Velocity of particle at \(n+1\)\textsuperscript{th} iteration

\(v_n\): Velocity of particle at \(n\)\textsuperscript{th} iteration

\(c_1\): acceleration factor related to \(g_{\text{best}}\)

\(c_2\): acceleration factor related to \(l_{\text{best}}\)

\(\text{rand1}(\cdot)\): random number between 0 and 1

\(\text{rand2}(\cdot)\): random number between 0 and 1

\(g_{\text{best}}\): \(g_{\text{best}}\) position of swarm

\(p_{\text{best}}\): \(p_{\text{best}}\) position of particle

The position is calculated by

\[
\text{CurrentPosition}_{[n+1]} = \text{CurrentPosition}[n] + v[n+1]
\]

\(\text{Current position } [n+1]\): position of particle at \(n+1\)\textsuperscript{th} iteration

\(\text{current position}[n]\): position of particle at \(n\)\textsuperscript{th} iteration

\(v[n+1]\): particle velocity at \(n+1\)\textsuperscript{th} iteration

where \(c_1\) and \(c_2\) are constants and are taken as 1.5. The weight factor (w) plays an important role in the search. Various studies are involved in the selection of w.

<table>
<thead>
<tr>
<th>PSO Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>(C_1)</td>
<td>1.5</td>
</tr>
<tr>
<td>(C_2)</td>
<td>1.5</td>
</tr>
<tr>
<td>(w)</td>
<td>0.9</td>
</tr>
<tr>
<td>(P)</td>
<td>50</td>
</tr>
<tr>
<td>Iterations</td>
<td>150</td>
</tr>
</tbody>
</table>
5. Result

The simulations are carried out on 15x15 Km$^2$ synthetic test system areas with fixed traffic. By comparing SPQV and uniformly generated random number, the selection of TTP and assignment of Erlang value is determined. Necessary coding for the simulations are developed using MATLAB 7.3 software. The antenna parameter settings used for calculations are given in Table 4. The values are initialized as per the following simulation parameters.

![Table 4. Simulation Parameters](image)

The algorithm effectively determines optimum number of mobile antenna locations to satisfy the objectives. The fitness plot is obtained and is observed to be very effective if it’s carried in terms of 50 iterations and over. Optimum solution is found out using 150 iterations.

![Fitness Plot](image)

6. Conclusion

PSO algorithm is proposed for optimizing all the design parameters such as site coordinates (x, y), transmitting power, and height and tilt angle of BS location problem. The maximization of service coverage and minimization of cost are considered as conflicting objectives. The antenna taken is sector for its coverage and power. The PSO parameters are initialized. The number of antennas needed for the particular cell is determined by the traffic demand. After the number of antennas is set the optimum locations for the antenna where maximum coverage is obtained is determined. The iterations are fixed as 50 for better optimum results. It is observed that PSO algorithm gives optimum locations for base station antenna placement where maximum coverage is obtained. Further the PSO can be iteratively repeated to obtain a better solution. It is observed that optimum solution is obtained at 150 iterations.
References


