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Design of station site selection for communication networks based on simulated annealing algorithm

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Abstract: *With the development of the scale of mobile communication technology, the scale of operation and the bandwidth of communication are getting larger and larger, but the coverage of base stations is getting smaller and smaller. In order to minimize the cost of establishing base stations while covering a large amount of services, this paper uses objective planning and establishes a mathematical model to solve the optimal establishment method of base station siting. At the same time, the weak coverage points are clustered so that the weak coverage points can be managed among themselves effectively. Therefore, the improved simulated annealing algorithm is used to solve the problem. Firstly, the original data is pre-processed and the service volume of weak coverage points is sorted from largest to smallest, and the accumulated service volume of the first 35917 weak coverage points has reached 90% of the total service volume. In other words, it can be considered that the base stations are selected from this part of the points, and finally the optimal solution is obtained, when 90% of the total service volume is reached, the lowest accumulated cost of building base stations is 5705, and the coordinates of all new base stations and the type of base stations built are derived from this.*

Keywords: *Simulated annealing algorithm, Simulated annealing algorithm improvement, Base station siting*

1. Introduction

The coverage of existing base stations in mobile communication networks is not sufficient, and more base stations need to be built to provide more coverage. The selection of new base station sites is particularly important. According to the known coverage area of the network, the weak coverage area of the known network is given, and a certain number of points are selected to build new base stations so that the weak coverage area is covered after the new base stations are built [1].

We simplify the weak coverage area by dividing the weak coverage area with small grids, and the center point of each grid is this weak coverage area, so we transform the weak coverage area into weak coverage points.

Each weak coverage point has different business volume. Considering the cost of establishing base stations and environmental factors, we cannot cover all weak coverage points, so we prioritize the weak coverage points with large business volume according to their business volume. To determine whether the weak coverage points are covered, the Euclidean distance between the newly built base and the weak coverage points is calculated, and when the distance is less than or equal to the coverage range of the newly built base, the weak coverage points are covered, and vice versa, the weak coverage points are not covered. According to the actual situation, the distance between the existing base station point and the new base station point and the new base station and the new site cannot be less than the given value.

For macro base station (coverage range 30, cost 10) and micro base station (coverage range 10, cost 1), the distance between the existing base station and the new base station and the new and station cannot be less than 10. 90% of the total service volume of the weak coverage point is covered by the planned base station. Based on the above information, the site selection is carried out and the coordinates and types of new base stations are calculated.

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2. Assumptions and notations

2.1. Assumptions

We use the following assumptions.

(1) The service volume of each weak coverage point coordinate is real and stable.

(2) The new base station established does not consider other external factors such as terrain factor.

(3) The network coverage of the existing base stations in the given area is stable.

(4) The sector of each station can be controlled.

2.2. Notations

The primary notations used in this paper are listed as Table 1.

Table 1: Notations

Notations	Description
P_i	Coordinates of the i-th weak coverage point
K_i	Coordinates of the i-th existing base station
Q_i	Coordinates of the i-th new base station
d	Distance thresholds between base stations
d_0	Base Station Coverage
d_i	The distance between Q_i and p_i
n_1	Number of micro-base stations
n_2	Number of macro base stations
f	Total Cost

3. Model construction and solving

3.1. Data pre-processing

The goal is to have 90% of the total traffic of the weak coverage points covered by the planned base stations, all of which are ranked (descending) according to the size of the traffic.

From Figure 1, we can analyze that the service volume of some weak coverage points is much larger than other weak coverage points. To deal with this part of points, the base station's will include these points in priority.

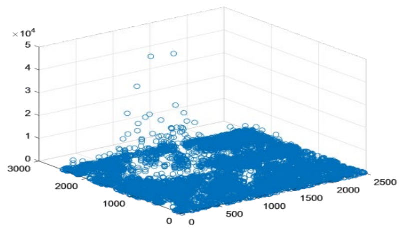

Figure 1: 3D plot of business volume at weak coverage points on coordinates

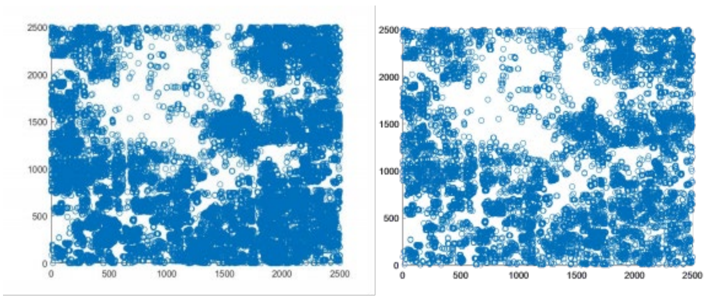

Figure 2: Original weak coverage points (left) and denoised weak coverage points (right)

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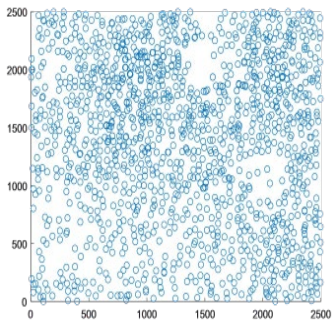

Figure 3: Distribution of existing base station sites

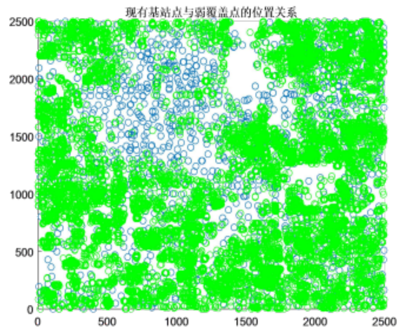

Figure 4: Relationship between existing base stations and weak coverage point locations

Base stations and weak coverage points and their relationships are shown in Figure 2 to Figure 4.

3.2. Model construction

3.2.1. Background of the model

We know the respective service volume w_i of N weak coverage points and the cost c_i of setting up base stations. How to fit them into the backpack M that covers 90% of the total service volume of the weak coverage points after the new base stations are built so that the cost of building all new base stations is minimized. Then the model of the problem is expressed as.

$$\min f(X) = \sum_{i=1}^{Ni} c_i x_{i^-} \tag{1}$$

$$\text{s.t.} \begin{cases} g(X) = \sum_{i=1}^{n} w_i x_i > M \\ x_i \in \{0,1\} \quad (i = 1, 2 \ldots, N) \end{cases} \tag{2}$$

3.2.2. Simulated annealing algorithm

The simulated annealing algorithm is a probability-based algorithm that is based on the idea of the solid annealing process: the solid is heated to a sufficiently high temperature and then allowed to cool slowly. When the solid is heated, the particles inside the solid gradually become disordered as the temperature rises and its internal energy increases, and then when it is slowly cooled, the sequence of particles gradually becomes ordered and finally reaches the ground state at room temperature, where the internal energy is reduced to a minimum. The solid annealing process is used to simulate the optimization problem, and E is simulated as the objective function, and the combined optimization problem corresponds to the objects, and all solutions correspond to the corresponding

The optimal solution corresponds to the state with the lowest energy, and the temperature T evolves into the control parameter t. According to the Boltzmann distribution, the probability of obtaining the optimal solution is maximized when the temperature reaches the bottom point[1]. the introduction of the Metropolis acceptance criterion makes the algorithm jump[2], so the importance of the initial solution is reduced.

Step 1.Initialize the cooling schedule.

Step 2.If the number of inner cycles reaches Lk at that temperature, go to step3.Otherwise, determine the chosen neighborhood structure and generate a new solution randomly from the neighborhood .

Step 3.If the stopping criterion m is satisfied, terminate the calculation; otherwise, go to step2.

Step 4. derive the optimal solution.

3.3. Model Solving

The SA algorithm is an iterative MenteCarlo-based solution strategy that uses stochastic probability

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to find the optimal solution of the objective function, which is based on the similarity between the annealing process of solids and combinatorial optimization problems. The global optimal solution of the objective function is found randomly in the solution space, i.e., the local optimal solution can probabilistically jump out and eventually converge to the global optimal [4].

The description of the solution using simulated annealing algorithm is as follows.

3.3.1. Space for Solution

$$S=\left\{(x(1),x(2),\ldots,x(n))\Big|\sum_{i=1}^{n^n} w(i)x(i)\le M, x(i)\in\{0,1\}\right\} \tag{3}$$

3.3.2. Objective function

$$\min f = n_1 + 10^{*} n_2 \tag{4}$$

$$\begin{gathered}\text{s.t.}\, f_{\text{Ye}} > \underset{i=1}{9} + \sum^{N} \text{trafic}(i) \\ d_i < 10\end{gathered} \tag{5}$$

3.3.3. New solutions generated

A weak coverage point p0 (x0 , y0) is randomly selected in the location chosen in the question, a micro base station or macro base station is randomly established, the distance between the coordinates of this weak coverage point and other weak coverage points pi (xi , yi) is calculated, the weak coverage point whose distance is smaller than the base station coverage point is taken out, and a weak coverage point is randomly taken out in the remaining coverage points to iterate on.

From the parametric formula.

$$\| x\|_2 = \sqrt{\sum_{i=1}^{N} x_i^2} \tag{6}$$

$$\|p_{\text{i}} - p_0\|_2 = \sqrt{\left(x-x_0\right)^2 + \left(y-y_0\right)^2} \tag{7}$$

3.3.4. Changes in service volume at weak coverage points and changes in the cost of establishing new base stations

According to the above-mentioned possible scenarios of new solution generation, the corresponding changes in the business volume of weak coverage points are.

$$\Delta f_{\text{Ye}} = \begin{cases} c(n1_i) \\ c\left(n2_i\right) \\ c\left(n1_i\right) - c\left(n2_i\right) \\ c\left(n2_i\right) - c\left(n1_i\right) \end{cases} \tag{8}$$

The corresponding change in the cost of setting up a new base station is.

$$\Delta f = \begin{cases} c(n1_i) \\ c\left(n2_i\right) \\ c\left(n1_i\right) - c\left(n2_i\right) \\ c\left(n2_i\right) - c\left(n1_i\right) \end{cases} \tag{9}$$

3.3.5. Acceptance guidelines

Since this problem is a constrained optimization problem, the expanded Metropolis criterion is used in the paper.

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$$\mathrm{p}=\begin{cases} 1 & f+\Delta f_{业} > 90\% * \sum_{i=1}^{N} traffic(i) \\ \exp(-\Delta f / t) & \text{Other situations} \end{cases} \tag{10}$$

3.4. Improvement of simulated annealing algorithm[5]

3.4.1. New solution generation method for improvement

The original data is analyzed, and the 180,000 weak coverage points are sorted to accumulate the summed service volume. It is found that when the 35916 weak coverage points are summed after sorting, the accumulated service volume has already reached 90%, i.e., there is a large difference in service volume between points among the 180,000 weak coverage points. Therefore, the priority of selecting new base stations is from these 35916 weak coverage points.

3.4.2. Improvement of the selection of base station type

In the pre-search process, we prioritize the high cumulative service volume as the main goal. That is, the probability of generating macro base stations is higher than that of micro base stations in the process of randomly determining the base station type.

In the later stage of the search, we prioritize the minimum cumulative cost as the main goal. That is, the probability of generating a micro-base station in the process of randomly determining the type of base station is greater than that of a macro-base station.

In summary, we choose the function.

$$y=e^{-\frac{\sum_{m=1}^{i}1}{\sum_{m=1}^{n}1}} \tag{11}$$

3.5. New model solution results

The coordinates of the selected sites and the type of base stations selected for each site, the total service volume of the weakly covered sites, and the total cost of establishing base stations are shown in Table 2.

Distribution map of new base stations and weak coverage points is shown in Figure 5.

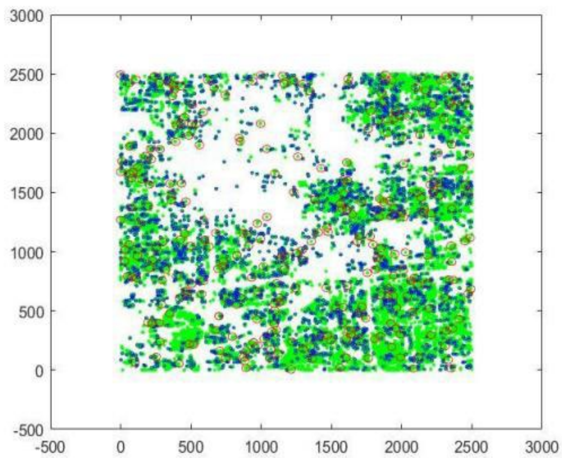

Figure 5: Distribution map of new base stations and weak coverage points

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Table 2: Coordinates of the selected station site

x-axis coordinates	y-axis coordinate	Base Station Type	Total cost
972	1238	1	5705
1314	1125	0	
753	1297	0	
892	2001	0	
1229	1894	0	
1000	1858	0	
1311	2005	0	
1611	2233	0	
629	2206	0	
1394	1798	0	
...			
1314	1125	0	

4. Conclusion

According to the optimally ranked base station locations, an improved simulated annealing algorithm is used to solve the optimal solution. With the cumulative service volume reaching 90 percent as the cutoff point, the optimal solution is finally derived as the lowest cumulative cost of establishing base stations 5705, with a total of 3041 base stations, and the coordinates of all new base stations and the types of base stations built are given. The coordinates and types of base stations are plotted and analyzed, and it is concluded that the base stations can effectively cover the areas with concentrated business volume and areas with large business volume, and then the model is considered to have a better and more efficient selection of the sites for the establishment of base stations.

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