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Research on Improved PSO in Communication Site Planning

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Abstract: *Aiming at the planning problem of mobile communication station location, this study first uses the base station distribution data to screen, and on this basis, establishes the objective function and constraint conditions of station number and station location positioning. Secondly, based on the basic particle swarm optimization algorithm and Yangwei particle swarm optimization algorithm, the original algorithm is optimized by adding inertia weight disturbance to obtain the optimal number of station sites and station location, and then the station location is clustered. It is concluded that the establishment of 455 macro base stations and 1902 micro base stations is the most suitable, and the weak coverage base stations are divided into 35 categories for management.*

Keywords: *Particle Swarm Optimization, Site Planning, Weak coverage points*

1. Introduction

With the development of 5G, the bandwidth of communication is getting larger and larger, but the coverage of base stations is getting smaller and smaller, so that the number of base stations needed to cover the same area becomes more. In addition, the types of base stations and antennas have also increased. This makes the planning of communication networks, especially the problem of site selection, more and more complex. The problem of site selection is: according to the coverage of the existing network antenna, a certain number of points are selected for the weak coverage area of the existing network, so that after the new base station is built on these points, the coverage problem of the weak coverage area of the existing network can be solved[1]. In the actual network planning, considering the construction cost of the base station and some other factors, sometimes it may not be possible to solve all the weak coverage areas. At this time, it is necessary to consider the factor of traffic volume and give priority to the weak coverage areas with high traffic volume. At the same time, it is also necessary in practice that the distance between new sites and between new sites and existing sites should not be less than or equal to a given threshold [2].

This study mainly improves the particle swarm optimization (PSO) algorithm to determine the coordinate points of the given base station in the current network, and then plans the site according to the coordinates, so that 90 % of the total traffic of the weak coverage point is covered by the planned base station. On this basis, the optimal station location and sector angle are given by fan signal radiation angle.

2. Materials and Methods

2.1 Data Sources and Analysis

This study uses the data of problem D in the 2022 mathorcup mathematical modeling competition (http://www.mathorcup.org/) for analysis and research. The normality test and descriptive statistics of the given data are carried out. It is found that the data basically conforms to the normal distribution and can be studied.

The general model of artificial neural network consists of four basic elements, which are:

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2.2 Introduction of the Method

2.2.1 Screening of data

Considering the service volume and computational efficiency of each weak coverage point, we use Excel to filter out weak coverage points with service volume less than 1 on the basis of existing base stations and delete them. After the data is filtered, the original 182807 weak coverage is reduced to 125806 weak coverage points.

2.2.2 Visualization of screening data

Through the data screened by the above method, the X coordinate and Y coordinate in the raster data are plotted as a scatter plot, as shown in Figure 1.

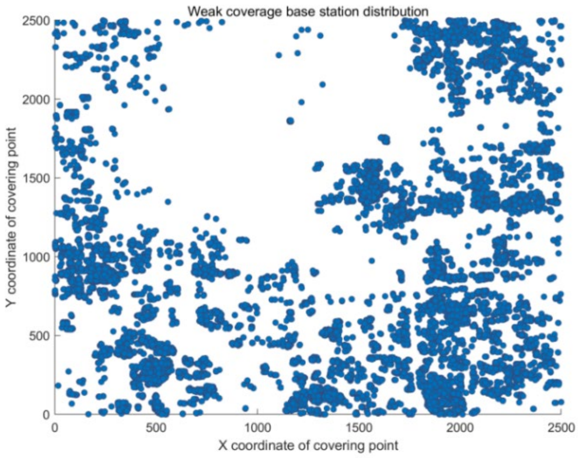

Figure 1: Weak coverage point location map

3. Model Establishment and Solution

3.1 Planning of the number of base stations

The planning of the number of base stations, that is, to establish a planning model, makes its business coverage large, and minimizes the cost of base station construction. In this regard, this paper comprehensively considers various constraints of base station location, and establishes an improved particle swarm optimization algorithm to optimize.

3.1.1 Establishment of site number planning mode

For the location planning of the base station, it is necessary to preferentially select the base station with the largest service volume. In addition, the base stations in this paper are divided into two categories: macro base stations and micro base stations. Therefore, we need to comprehensively consider the two types of base stations. In the case that 90 % of the total traffic of the weak coverage point is covered by the planned base station, the coordinates of the selected site and the type of base station selected for each site are given. And the topic has given the cost of the two types of base stations, so not only simply consider the service volume, but also make the cost of building the station optimal[3]. Finally, we decide to establish a mixed programming model, so that the service quantity of the weak coverage point is the largest and the base station cost is the smallest.

The established objective function and constraints are as follows.

$$\max u = \frac{b}{f} \tag{1}$$

$$f = 10N_1 + N_2 \tag{2}$$

ISSN 2616-5775 Vol. 6, Issue 6: 84-89, DOI: 10.25236/AJCIS.2023.060613

$$.T\begin{cases}\sqrt{(x_{mn}-x_{pmn})^2+(y_{mn}-y_{pmn})^2}\le 30\\ \sqrt{(x'_{mn}-x_{pmn})^2+(y'_{mn}-y_{pmn})^2}\le 10\\ \sqrt{(x_{mn}-x_{q})^2+(y_{mn}-y_{q})^2}\ge 10\\ \sqrt{(x'_{mn}-x_{q})^2+(y'_{mn}-y_{q})^2}\ge 10\\ \\ b\ge 6333761\\ 0\le m\le 2499\\ 0\le n\le 2499\\ N_1\le 125806\\ N_2\le 125806\end{cases}\tag{3}$$

Where b represents the weak coverage point after the site planning. $p=1,2,3\cdots 125806$,

$q=1,2,3\cdots 1474$, f indicates base station cost, N_1 and N_2 represent the number of macro base stations and micro base stations respectively.

3.1.2 Model solution of particle swarm optimization (PSO)

(1) Original particle swarm optimization (PSO)

Suppose that in a D-dimensional target search space, there are N particles forming a community, where the i-th particle is represented as a D-dimensional vector[4].

$$x_i=(x_{i1},x_{i2},\cdots,x_{iD})\qquad i=1,2,\cdots,N\tag{4}$$

The flight speed of the i-th particle is also a D-dimensional vector.

$$V_i=(V_{i1},V_{i2},\cdots,V_{iD})\qquad i=1,2,\cdots,N\tag{5}$$

The optimal position searched by the i-th particle so far is the individual extremum.

$$P_{best}=(P_{i1},P_{i2},\cdots,P_{iD})\qquad i=1,2,\cdots,N\tag{6}$$

The optimal position searched by the whole particle swarm so far is the global extremum.

$$g_{best}=(g_1,g_2,\cdots,g_D)\tag{7}$$

When finding these two optimal values, the particle swarm updates its velocity and position as follows[5].

$$V_{ij}(t+1)=V_{ij}(t)+c_1r_1(t)\left[P_{ij}(t)-x_{ij}(t)\right]+c_2r_2(t)\left[P_{gi}(t)-x_{ij}(t)\right]\tag{8}$$

$$x_{ij}(t+1)=x_{ij}(t)+V_{ij}(t+1)\tag{9}$$

Where c_1, c_2 are learning factors, also known as acceleration constants, r_1,r_2 is an equilibrium random number of $[D,1]$, $i=1,2,\cdots,D$, V_{ij} is the velocity of particles, $V_{ij}\in\left[-V_{\max},V_{\max}\right]$, $V_{\max}$ are constants[6].

(2) Yang Wei improved particle swarm optimization algorithm[7]

$$V_{ij}(t+1)=w\cdot v_{ij}(t)+c_1r_1(t)\left[P_{ij}(t)-x_{ij}(t)\right]+c_2r_2(t)\left[P_{gi}(t)-x_{ij}(t)\right]\tag{10}$$

$$x_{ij}(t+1)=x_{ij}(t)+v_{ij}(t+1)\tag{11}$$

ISSN 2616-5775 Vol. 6, Issue 6: 84-89, DOI: 10.25236/AJCIS.2023.060613

w is the inertia weight. The larger w is, the stronger the global convergence ability is, and the weaker the local convergence ability is. Experiments show that when w inertia weight is between 0.9 and 1.2, the particle swarm optimization algorithm has a fast convergence speed. When $w > 1,2$, it is easy to fall into local extremum[8].

(3) LDW particle swarm optimization algorithm[9]

$$V_{ij}(t+1) = W \cdot V_{ij}(t) + c_1 r_1(t)\left[P_{ij}(t) - x_{ij}(t)\right] + c_2 r_2(t)\left[P_{gi}(t) - x_{ij}(t)\right] \tag{12}$$

$$W_d = W_{\max} - \frac{(w_{\max} - w_{\min}) \cdot t}{T_{\max}} + At \tag{13}$$

Where $A_t \in \{0,0,1\}$ is the inertia weight perturbation constant.

In the above case, there will still be particles gathered around the optimal particle into a local optimum. Therefore, the following improvements are made by adding a parameter $r \in [0.9,1,1]$ [10].

$$V_{ij}(t+1) = W_{dr} \cdot V_{ij}(t) + c_1 r_1(t)\left[P_{ij}(t) - x_{ij}(t)\right] + c_2 r_2(t)\left[P_{gi}(t) - x_{ij}(t)\right] \tag{14}$$

$$W_{dr} = (W_{\max} - \frac{(w_{\max} - w_{\min}) \cdot t}{T_{\max}}) \cdot r + At \tag{15}$$

The three algorithms mentioned above are used to solve the objective function, and the results are shown in Table 1.

Table 1: Result

Algorithm	Macro base station	Micro base station	Cost	Traffic
PSO	1034	3325	13665	90.88%
Yangwei PSO	584	2134	7974	91.24%
LDW PSO	455	1902	6452	94.6%

From the data in Table 1, it can be seen that the traffic coverage rate of the three algorithms has reached more than 90 %, and the effect is good. However, although the traffic coverage rate solved by the conventional particle swarm optimization algorithm has reached more than 90 %, the algorithm has fallen into a local optimal solution and cannot guarantee the minimum construction cost of the base station. The traffic coverage rate of LDW PSO is very high, and the cost is also lower than the other two algorithms. Therefore, the number of base stations obtained by LDW PSO is the best.

3.2 Planning of Fan-shaped base station coverage

In the solution of the planning model established above, the optimal number and type of station sites are obtained. On this basis, the main direction and coverage of the sector area are discussed, and the station site planning model is established and solved by MATLAB.

3.2.1 Establishment of site planning model

Firstly, we use software to draw a schematic diagram of the base station sector area, as shown in Figure 2.

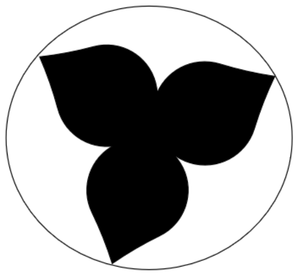

Figure 2: Sector area diagram

ISSN 2616-5775 Vol. 6, Issue 6: 84-89, DOI: 10.25236/AJCIS.2023.060613

Among them, the fan-shaped area planning of macro base station and micro base station meets the same constraints, so the schematic diagram of the two base stations is only the radius of the circular area is different. The radius of the macro base station signal range is 30, and the radius of the micro base station is 10. An integer programming model is established below.

$$\max V = \sum_{i=1}^{n} A_i x_j + \sum_{i=1}^{n} A_i y_j$$

$$s.t\begin{cases} \sqrt{(x_u - x_0)^2 - (y_u - y_0)^2} \le 30 \\ \sqrt{(x_v - x_0)^2 - (y_v - y_0)^2} \le 10 \\ \cos w = \dfrac{\sum x_j^2 + \sum y_j^2 - \sum\sum x_j y_j}{\sum x_u y_u + \sum x_v y_v} \\ w = \pi/3 \\ \cos w' = \dfrac{\sum x_u^2 + \sum y_u^2 - \sum\sum x_u y_u}{2\sum x_j^2 y_j^2} \\ \cos w'' = \dfrac{\sum x_v^2 + \sum y_v^2 - \sum\sum x_v y_v}{2\sum x_j^2 y_j^2} \\ w'、w'' \ge \pi/4 \\ x_j, y_j = 0,1 \end{cases} \tag{16}$$

Where A_i is the service quantity of the base station, (x_u, y_u) and (x_v, y_v) is the coordinates of the macro base station and the micro base station respectively, w is the radiation angle of the sector area, and w'、w'' are the angle of the radiation main direction of any two sector areas.

3.2.2 Solution of site planning model

Using the particle swarm optimization algorithm established above to solve, the macro base station and micro base station distributed according to the number of sectors are obtained, and the coordinate distribution map of the station site is visualized as a scatter plot. The macro base station is shown in Figure 3, and the micro base station is shown in Figure 4.

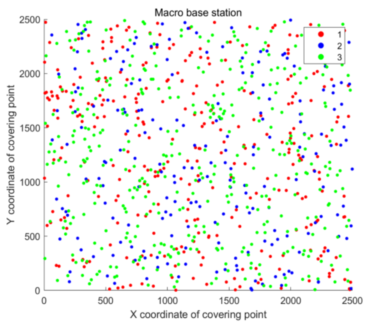

Figure 3: Macro base station location

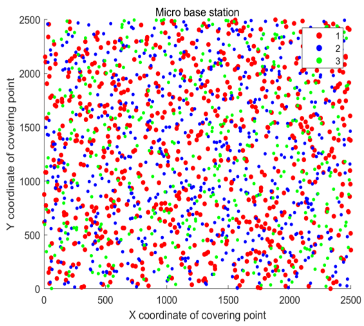

Figure 4: Micro base station location

3.3 Systematic clustering of weak coverage site

After planning the coordinate points of each communication site, the weak coverage site is systematically clustered to better manage the business. In this study, the system clustering based on the square Euclidean distance is divided, and there is an iterative process in the clustering process. This iterative process can optimize the clustering length of the weak coverage points at the edge, thus making up for the unreasonable classification of the clustering point boundary by the traditional distance-based clustering algorithm. The square Euclidean distance calculation formula is as follows.

ISSN 2616-5775 Vol. 6, Issue 6: 84-89, DOI: 10.25236/AJCIS.2023.060613

$$d(\vec{x}_1,\vec{x}_2)=\sum_{k=1}^{p}(x_{1k}-x_{2k})^2 \tag{17}$$

Using the above method, the aggregation coefficient of each stage in the iterative process can be obtained, and the optimal clustering class number is 35 by the elbow rule test. The clustering results are visualized as shown in Figure 5.

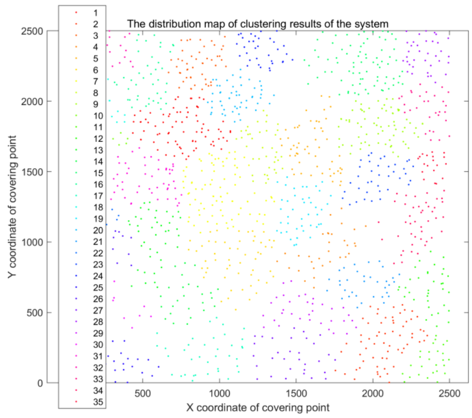

Figure 5: Cluster distribution map

4. Conclusions

Through the analysis of this study, first of all, the base station positioning data provided is removed from the base station with service coverage greater than 1, and then the filtered data is visualized. Secondly, based on various factors, the objective function and constraint conditions that need to be optimized are determined. Through the improvement of the particle swarm optimization algorithm in this study, the optimal number of base station sites is 455 macro base stations and 1902 micro base stations. The service coverage rate reaches 94.6 %, and the location of the site is optimized. Finally, we use the optimized site location for system clustering to obtain 35 types of weak coverage base station distribution maps, so as to better carry out service coverage.

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