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Research on site selection of communication network based on site planning

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Abstract: In the era of big data, communication networks play an important role in people's daily lives. However, due to the influence of the geographical environment and population density on the coverage area of each base station, it is urgent to increase the number of base stations to make up for the impact of the environment. Aiming at the problem of site planning and spatial clustering under the communication network, this paper uses the multi-objective programming model to design a feasible scheme for the site planning problem under various conditions.

1. Introduction

Currently, with the advancement of 5G technology, the scale of communication bandwidth has been further developed, but the coverage area of each base station is affected by the geographical environment and population density, and there is an urgent need to increase the number of base stations to compensate for the environmental impact [1]. For weak coverage areas, it is necessary to add some different types of base stations to achieve a certain level of coverage and build a model to achieve the goal of site planning [2]. Since the coverage of two base stations decreases gradually with increasing angle, considering the influence caused by constraints such as cost, under this condition, the site selection and angle results need to be given when the newly added stations can cover 90% of the total service volume[3].

2. Construction and Solution of Site Planning Model

2.1 Spatial feature analysis of weak coverage area

2.1.1 Spatial distribution of traffic

From Figure 1, we can see that the traffic distribution in the weak coverage area is very uneven, the largest point traffic can reach 47795, and the smallest point traffic is only 0.000192. Among all the points, only 20.4% of the points have a traffic volume above 25, and the median of the traffic volume of all the points is only 3.6043. In the process of site selection planning, we need to prioritize the distribution of new base station site selection for weak coverage points with high traffic volume[4].

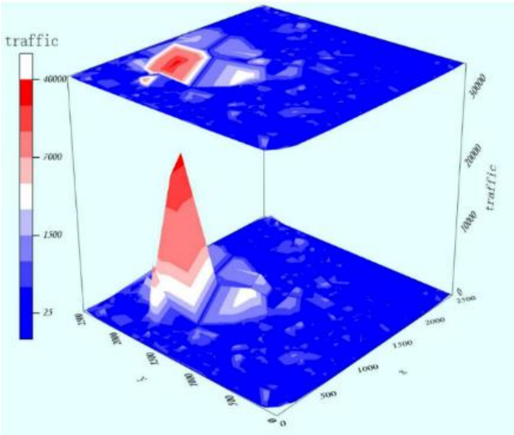

Figure 1 The coordinates of each business point and the size of the business volume

2.1.2 Spatial distribution of base stations in the existing network

We use Origin to draw the contour map of the traffic volume and superimpose the distribution scatter diagram of the existing network base stations for comprehensive analysis. From Figure 2, we can see that in the area with large traffic volume, the distribution of the existing network base stations is quite small, while in some areas where there is no traffic or the traffic is close to zero, there are many base stations on the existing network[5]. Obviously, the current distribution of base stations is very unreasonable. We consider establishing more new base stations with different coverage capabilities at a certain distance from the existing base stations under certain conditions.

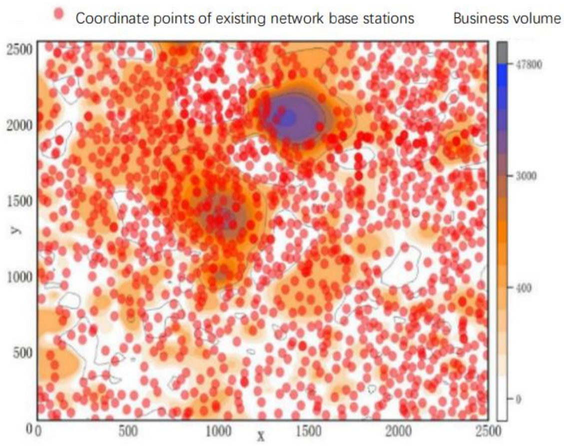

Figure 2 Weak coverage areas where new base stations should be added

2.2 Explore the establishment sequence of the two base stations

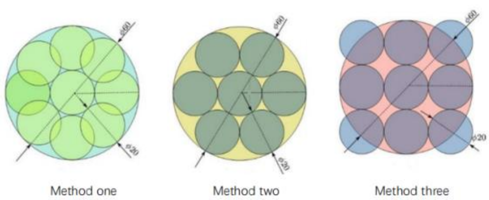

Figure 3 Macro base station and micro base station

We know that the coverage radius of the macro base station is three times that of the micro base station, the area is nine times that of the micro base station, and the cost is ten times that of the micro base station. We set up the following three methods to discuss the establishment of new macro base stations and micro base stations(Figure 3). In the order between base stations, the loss areas S_1, S_2, and S_3 refer to the areas that are not covered by the micro base station in the macro base station.

Method 1:

$$S_1 = S_{sum} - nS_{small} + nS_{heavy} = 3.14*R^2 - 3.14*9*r^2 + 8*2*\left(\frac{\theta*3.14*r^2}{360} - r*r*\sin\theta*0.5\right)$$
$$= 3.14R^2 - 28.26r^2 + 16*\left(0.0087\theta r^2 - 0.5r^2\theta\right) \quad (1)$$
$$=144.528$$

Method 2:

$$S_2 = S_{sum} - nS_{small} = 3.14*R^2 - 7*3.14*r^2 = 627 \quad (2)$$

Method 3:

$$S_3 = S_{sum} - nS_{small} - mS_{\Delta} = 3.14*R^2 - 3.14*5*r^2 - 48S_r + 48S_t$$
$$\approx 3.14*R^2 - 3.14*5*r^2 - 4*\left(\frac{\alpha*3.14*r^2}{360} - 0.5r^2\sin\alpha\right) \approx 833 \quad (3)$$

Table 1 Comparison of three methods

Method	Loss	Cost (only for micro base stations)
Method 1	144．53	90
Method 2	627	70
Method 3	833	90

As can be seen from Table 1, compared with the latter two distribution methods, method 1 has the largest overlap area, but the smallest loss area. Combined with the information reflected in the above chart, if a new micro base station is established first and then a macro base station is established, it will cause a lot of area loss. To reduce the area loss, it is necessary to increase the number of micro base stations, which will inevitably increase more costs. Based on this, we should give priority to the distribution of macro base stations in this question, and then build new micro base stations in the remaining area to achieve more than 90% of the site coverage.

2.3 Establishment of site planning model under multi-objective

We plan to give priority to the establishment of two different types of base stations in weak coverage areas with high traffic volume, and comprehensively consider the cost, coverage capacity, and threshold range of new and old base stations required to establish a base station, and establish a multi-objective planning model. The specific steps are as follows:

Data preprocessing

STEP1: Use the condition that the threshold is 10, narrow the optimization range, and get all the points (x_i, y_i) that may establish the base station, the coordinates of the original base station are recorded as (x_o, y_o) $(o = 1,2,3 \cdots 1475)$ the established constraints are as follows:

$$\text{s.t.}\begin{cases}10 \le \sqrt{(x_i - x_o)^2 + (y_i - y_o)^2} \\ 0 \le x_i < 2500 \\ 0 \le y_i < 2500 \\ x_i \in N^+ \\ y_i \in N^+\end{cases} \tag{4}$$

STEP2: Clean the data points, remove the points (noise points) whose business volume is less than P, and reduce the number of samples. Regarding the selection of the set limit P, it is necessary to ensure that the sum of the business volume greater than P is greater than or equal to the total business volume 90% (to avoid washing out some important points, we set P to 0.1).

$$\text{s.t}\begin{cases}\text{traffic}_i > P \\ \sum_{i=1}^{182808} \text{traffic}_i \times 0.9 \le \sum_{i=1}^{k} \text{traffic}_k\end{cases} \tag{5}$$

STEP3: In the point$(x_i, y_i)$where the base station may be established, it is necessary to judge which base station is appropriate to establish at the point of the set $\{(x_i, y_i)\}$. The specific process of the evaluation index here is as follows:

Let the coordinates of the weak coverage point is (x_r, y_r), the corresponding traffic is recorded as traffic$_r$, and the point where the base station may be established(x_i, y_i)

If the point is a macro base station, the flag bit Flag is recorded as 1, and the corresponding total service volume is recorded as sum_h

If the point is a micro base station, the flag bit Flag is recorded as 0, the corresponding total amount of business is recorded assum_w, and the following judgments are made for each point$(x_i, y_i)$where a base station may be established.

Divide the points(x_i, y_i)(full set)that may establish a base station into a point set $\{(x_h, y_h)\}$that has a relatively high-cost performance for establishing a macro base station and a point set$\{(x_w, y_w)\}$that has a relatively large cost performance for establishing a micro base station,

$$\{(x_h, y_h)\} + \{(x_W, y_w)\} = \{(x_i, \quad y_i)\} \tag{6}$$

First determine the location of the macro base station

STEP4: Find the point where the line connecting the centers of the two macro base stations is greater than 60. The purpose is to determine that the two macro base stations do not intersect, and each point that needs to be judged$(x_i, y_i) \in (x_h, y_h)$, and finally get the need to establish a macro base station The set$\{(x_H, y_H)\} \subseteq \{(x_h, y_h)\}$, the number of macro base stations is *H*, and the specific constraints are as follows:

$$\text{s.t.}\begin{cases}\sqrt{(x_i - x_{i+t})^2 + (y_i - y_{i+t})^2} \ge 60 \\ 1 \le t \le h-1 \\ 0 < i \le h \\ \cdot i \in N^+\end{cases} \tag{7}$$

STEP5: Calculate the traffic traffic_H covered by the macro base station at this time, the difference S between the calculation of the total traffic sum_H and 90% of the total traffic volume is S, as the lower limit of the traffic volume traffic_W that needs to be covered by the micro base station, the specific formula of the total traffic sum_w is as follows:

$$S = 6350000 - sum_w (sum_H \geq S) \tag{8}$$

Then determine the location of the micro base station

STEP6: In the point$\{(x_w, y_w)\}$where establishing a micro base station has a relatively high-cost performance, select the point$(x_{Wei}, y_{Wei})$where the micro base station is actually to be established, and the number of micro base stations is W. Each point sought is$(x_j, y_j) \in \{(x_w, y_w)\}$.Among them, the constraint condition 1 is to try not to overlap as much as possible, and finally$\{(x_{Wei}, y_{Wei})\}$is obtained; the total amount of business to be covered is greater than or equal to sum_w as the constraint condition 2. The goal is to minimize the number of points (x_{Wei}, y_{Wei}) of micro base stations, that is, under the condition that the number and location of macro base stations are determined, the number and location of micro base stations are selected to ensure the lowest cost. The specific formula is as follows:

Objective function:

If the latter cost $C_{(i+1)}$ is smaller than the former cost C_i, the cost C_i will be updated, otherwise it will not change, and the number and location information of W (micro base stations) will be recorded at the same time. The specific function is as follows:

$$C_i = 10 \times H \text{ (Micro base station) } + 1 \times W \text{(Macro base station)} \tag{9}$$

Restrictions:

$$\text{s.t. } 1 \cdot \begin{cases} \sqrt{(x_j - x_r)^2 + (y_j - y_r)^2} \geq 20 \\ 1 \leq p \leq w-1 \\ 0 < j \leq w \\ j \in N^+ \end{cases} \tag{10}$$

$$\sqrt{(x_j - x_r)^2 + (y_j - y_r)^2} \leq 10 \tag{11}$$

$$sum_w = sum_w + traffic_r \tag{12}$$

$$\text{s.t. } 2 \begin{cases} sum_w \geq S \\ 0 < j \leq W \\ j \in N^+ \end{cases} \tag{13}$$

2.4 Solving the multi-objective site planning model

After data preprocessing, the positions of all the points where the base station can be established are shown in Figure 4. The blank point represents the limit of 10 between the base station and the existing base station. Among the weak coverage points, the restricted points (white points) have been preferentially excluded, and all remaining points (blue points) are allowed to establish base stations.

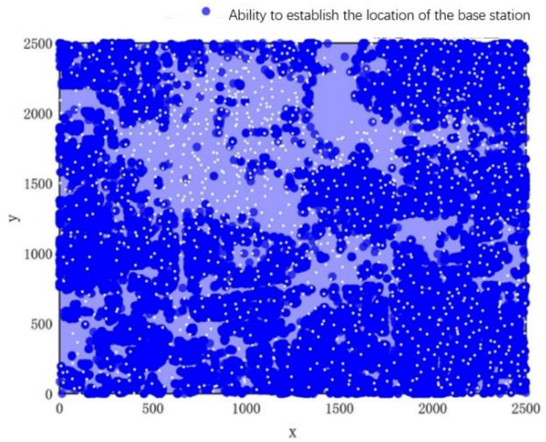

Figure 4 All points of the base station can be established after data preprocessing

We use matlab to solve the above constraints, and finally get the specific location information of the macro base station and the pseudo base station as shown in Figure 5.

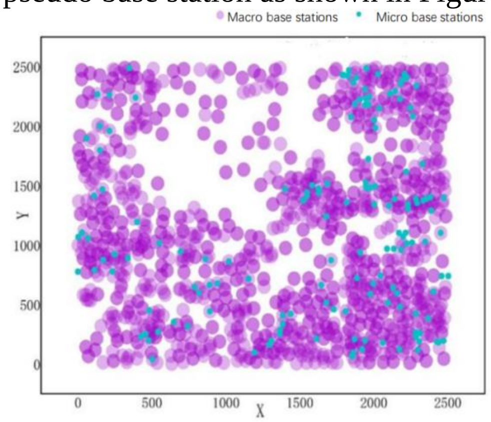

Figure 5 Schematic diagram of macro base station and micro base station

3. The establishment and solution of the site selection planning model based on the included angle of the main direction

3.1 Model Preparation

3.1.1 60°partition method

STEP1: For different types of base stations, determine the coordinates (x_{in}, y_{in}) of the service points that fall on the established base station, and the coordinates of the new base station to be established are (x_0, y_0). For macro base stations and micro base stations, we use the distance between two points to determine the distance:

(1) When $R_h \le 10$, set $\{(x_{wei}, y_{wei})\} \subseteq \{(x_{inwei}, y_{inwei})\}$:

$$R_w = \sqrt{(x_{wei} - x_0)^2 + (y_{wei} - y_0)^2} \le 10 \tag{14}$$

(2) When $R_h \le 30$, set $\{(x_H, y_H)\} \subseteq \{(x_{inH}, y_{inH})\}$:

$$R_h = \sqrt{(x_H - x_0)^2 + (y_H - y_0)^2} \le 30 \tag{15}$$

STEP2: Calculate θ_{in} within this range. At this time, the service point contains four attributes $(x_{in}, y_{in}, \theta_{in}, \text{traffic})$. When a point (x_{in}, y_{in}) is within the range of the base station, its attributes(θ_{in}, traffic)are considered:

$$\theta_{in} = \arccos\left(\frac{D_H}{|x_{in} - y_0|}\right) = \arctan\frac{|y_{in} - y_0|}{|x_{in} - y_0|} \quad (16)$$

STEP3: Since the main direction differs by 60 °, three different areas are divided every 60 °, and the total traffic volume of all coverage points in each area is calculated, as shown in Table 2 and Figure 6.

Table 2 Interval division

interval	angle
1	$(0, 60^{\circ})$
2	$(60^{\circ}, 120^{\circ})$
3	$(150^{\circ}, 240^{\circ})$

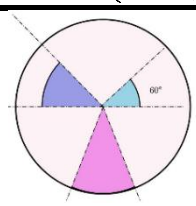

Figure 6 60 °partition method

3.1.2 45 °partition method

STEP1 and STEP2 of the 45 °partition method and the 60 °partition method are roughly the same. Since the main direction is different by 45 °, the 45 °

For the boundary, there are 8 partitions in total. We distinguish the corresponding colors on each partition table. The partition results are shown in Table 3 and Figure 7.

Table 3 Interval division

interval	angle
1	$(-30^{\circ}, 30^{\circ})$
2	$(15^{\circ}, 75^{\circ})$
3	$(60^{\circ}, 120^{\circ})$
4	$(105^{\circ}, 165^{\circ})$
5	$(150^{\circ}, 210^{\circ})$
6	$(195^{\circ}, 255^{\circ})$
7	$(240, 300^{\circ})$
8	$(285, 345^{\circ})$

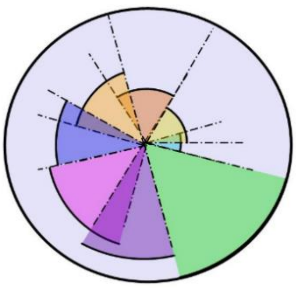

Figure 7 45 °partition method

For all points that fall within the range, determine the partition according to its θ_{in}, add its traffic to the corresponding partition, select the first three traffic and the largest one as the main direction, and then determine the total amount of service coverage of each base station point in turn.

3.1.3 Non-overlapping partition method

Because the area corresponding to the main direction is 60 °, that is, the main direction axis is the center, and the left and right are symmetrical ±30 °. In order to ensure that no overlap occurs in each direction, the circular area is first divided into three 120 °, for each 120 °, select a main direction sector area as the preferred sector, taking the M area 120 °in the upper right as an example, the segmentation method is shown in Figure 8.

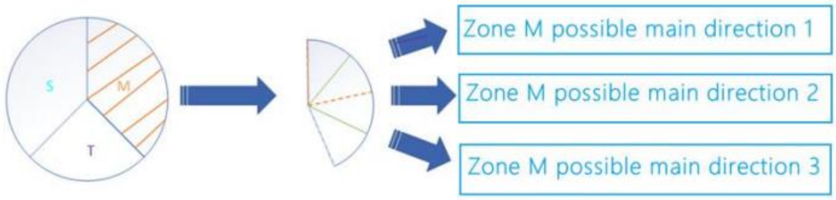

Figure 8 Non-overlapping zoning method

For the M area 120 °in the upper right, three possible areas are set as potential main direction areas. According to the actual calculation conditions of STEP1 and STEP2, the business volume falling into the service point in the 120 °direction is calculated respectively. The business volume calculated by the three predetermined areas, select the area with the largest traffic volume as the main direction area of the 120 °area where it is located. The specific division of the M area 120 °is as Table 4:

Table 4 120 °division of M area

interval	angle
1	$(30^{\circ},90^{\circ})$
2	$(-30^{\circ},30^{\circ})$
3	$(-15^{\circ},45^{\circ})$

For the S area 120 °and the T area 120 °, the division method is the same as that of the M area 120 °. Since the difference of each area is 120 °, the condition of the main direction difference of 45 °has been met, and the division results of each area are different by 120 °and 240 °, S zone 120 °and T zone 120 °The specific division results are shown in Table 5 and 6:

Table 5 120 °division of S area

interval	angle
1	$(150^{\circ},210^{\circ})$
2	$(90^{\circ},150^{\circ})$
3	$(105^{\circ},165^{\circ})$

Table 6 120 °division of T area

interval	angle
1	$(270^{\circ},330^{\circ})$
2	$(210^{\circ},270^{\circ})$
3	$(225^{\circ},285^{\circ})$

3.2 The solution of the location model

The Table 7 shows the three methods of 60 ° partition method, 45 ° partition method, and non-overlapping partition method. Finally, the coverage rate of the total traffic volume of the newly built station covering the weak coverage point is obtained:

Table 7 Total business volume coverage of the three methods

Model	Coverage
60 °partition method	27%
45 °partition method	42%
Non-overlapping partition method 45%	45%

From the above table, we can see that the coverage rate of 90% of the maximum coverage business obtained by the three methods is only 45%, which is far less than 90% of the total business that needs to be judged. From this, we can make a judgment, the new station cannot cover 90% of the total business volume.

In the end, the optimal site and sector angles we obtained are shown in Table 8:

Table 8 Optimal address and sector angle

Macro base station					Micro base station				
x	y	Theta1	Theta2	Theta3	x	y	Theta1	Theta2	Theta3
818	2020	288	243	333	1787	1403	252	207	297
713	2013	288	243	333	2491	758	216	171	261
2305	291	180	135	225	1221	2425	36	-9	81
700	1953	180	135	225	2104	1824	180	135	225
949	2293	180	135	225	2324	1841	180	135	225
1796	1239	180	135	225	256	250	216	171	261
1295	1193	252	207	297	1001	2320	216	171	261
1359	1514	108	63	153	408	914	252	207	297
1794	1873	108	63	153	756	1851	252	207	297
99	1755	72	27	117	1037	1899	252	207	297
2457	209	216	171	261	1219	1590	252	207	297
549	1917	324	279	369	1468	319	216	171	261
818	2020	288	243	333	652	1983	216	171	261
713	2013	288	243	333	2367	220	72	27	117
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Due to too many data points, we only select a part of macro and micro base stations to display the results.

4. Conclusion

In this paper, by establishing the station planning model and zoning design, the optimal station site and sector angle are obtained, and the coverage area of the base station, which is affected by geographic badlands and population density, is solved, and this planning study can provide a good reference for future base station location allocation.

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