

Site Selection Planning of Urban Base Station

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Abstract. TWith the development of mobile communication technology, the coverage quality of the network began to become an important measure of a regional communication network. With the development of 5G technology, the communication bandwidth is increasing, the coverage of the base station is getting smaller and smaller, and the types and signal coverage characteristics of base stations are also different. Therefore, the problem of site selection and planning of base stations in cities begins to become more prominent. Based on the principle of priority business volume and the cost performance of base station, this paper establishes a set of models to solve the site selection planning problem of urban base station. In short, in view of the base station construction planning problems in cities, this paper establishes the relevant model and algorithm, and gives a solution based on the principle of giving priority to the business volume requirements and the cost of base station construction.

Keywords: Exploratory data analysis and calculation (EDA), Ranking-based target-first solution method.

1. Problem Restatement

With the development of mobile communication technology, the coverage quality of the network began to become an important measure of a regional communication network. With the development of 5G technology, the communication bandwidth is increasing, and the coverage of base stations is getting smaller and smaller. According to the existing facilities, give the weak coverage area in the city, and build the base stations in the appropriate location, this is the site selection problem. Considering the construction cost of base station, business volume, base station sector angle and other factors, the optimization of base station location for weak network coverage areas has become more and more complex. Based on the principle of "priority solution to high service requirements", we choose the appropriate location for base station construction. The construction of base stations in these areas can effectively solve the problem of weak network coverage in some regions in the city [1-3].

Problem 1: divides the given area into a grid of 2500×2500, According to the existing network weak coverage position coordinates and business volume, the base station model and the distance threshold between the new base station and the original base station, and gives the appropriate base station construction location and the corresponding base station model [4-6]. 90% of the business volume requirements can be met, the site of the base station can only be selected in a given grid coordinate, and the coverage area of the base station can be modeled as a standard circle [7-9].

Problem 2: A further analysis shows whether the optimal site and sector angle conditions can meet the requirements of the total business volume by 90% of the base station signal [10]. If possible, the optimal site and sector angles planning are given, otherwise the optimal site and sector angles planning and the maximum proportion of the total business volume are solved.

2. Problem analysis

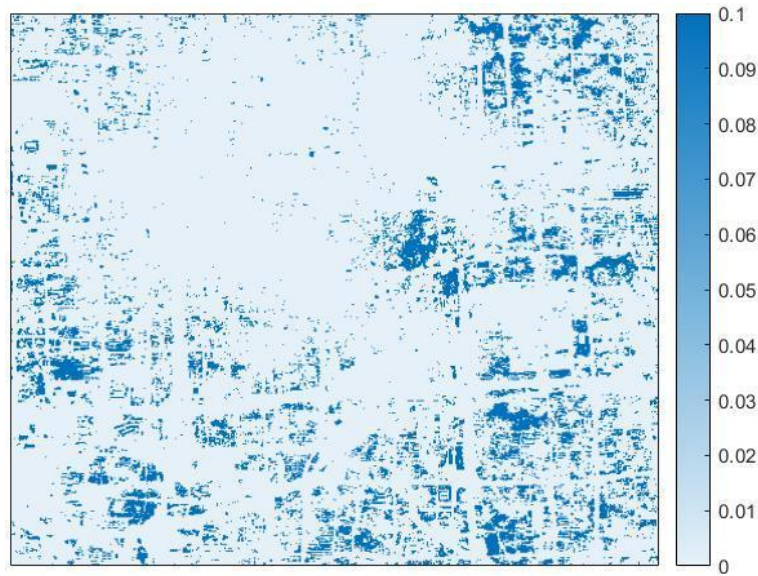


Figure 1. Weak coverage points

As can be seen from the figure 1, the distribution of the raw data presents a strong "non-convexity", so the density-based clustering method is a better clustering method when processing the raw data. At the same time, the amount of raw data is very huge, but 90% of the business volume is concentrated in the top 60,000 sets of data sorted by business volume from large to small. Therefore, data cleaning is very important.

Problem 1 The spacing threshold between base stations is 10, indicating that the spacing between new base station and existing base station is at least 10. Moreover, when a new base station is built, it should be included into the collection of existing sites to participate in the constraints of the next base station.

Problem 2 This problem adds the sector of the base station on the basis of problem 1. The analysis of problem 2 can be combined with the existing model of problem 1 for further optimization. Polar coordinates are used to characterize the sector of base stations, introducing new variables and related constraints to solve the problem. The general idea of solving the solution is the same as problem 1, that is, on the basis of limited satisfaction business volume, taking into account the cost performance, to obtain the optimal solution of the base station location.

3. Model building and solution for Problem 1

Problem 1 can be abstracted as the following mathematical model:
objective function:

$$\min\{C = \sum C_i\} \quad (1)$$

Constraint condition:

$$W = \sum W_i \geq 0.9W_s \quad (2)$$

$$X_i, Y_i \in Z \cap [0, 2500) \quad (3)$$

$$Q = \{(X, Y) | (X_i - X)^2 + (Y_i - Y)^2 \leq R^2, X \in Z, Y \in Z\}, Q \notin A \quad (4)$$

That is to words, under the premise that the coordinates of the new base station are integer, and the threshold distance between the base stations meet the business volume index, the base station construction planning scheme that can meet 90% of the total business volume: the coordinates (X_i , Y_i of each base station) and the type of base station. As shown in Figure 2 and Figure 3.

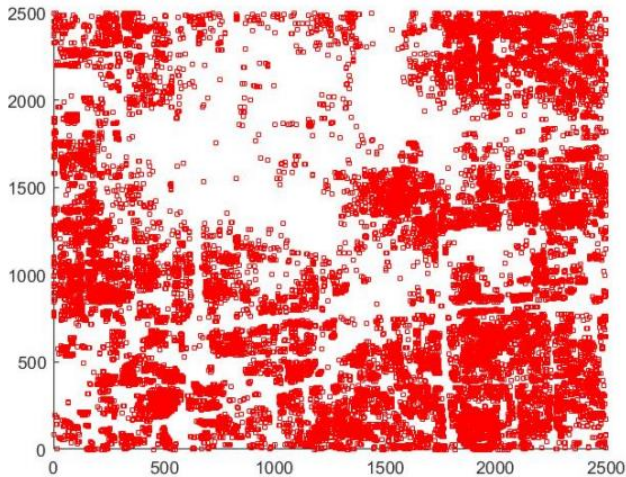


Figure 2. Before data cleaning

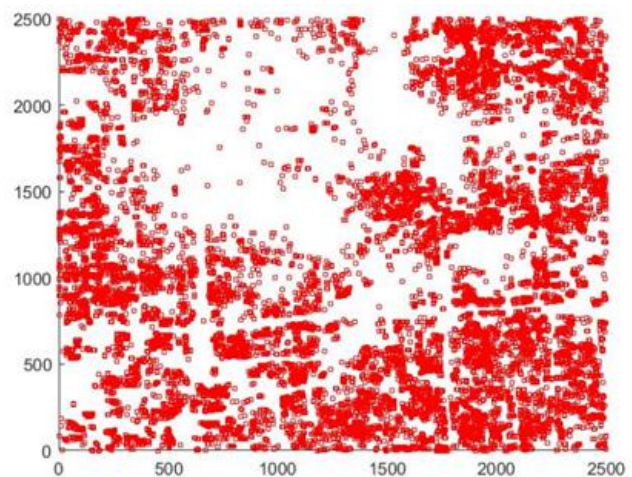


Figure 3. After data cleaning

According to the traffic volume of each weak coverage point, the weak coverage points are sorted, and the point with the largest traffic volume is selected for the construction of the base station. The use efficiency P of macro and micro base stations is used to select the type of base station. After the base station is selected, the points covered by the new base station are removed from the feasible area, and the remaining weak coverage points are sorted, and the cycle is repeated until the base station construction meets the requirement of 90% of the total traffic. This ensures that the cost of base station construction can be avoided when the traffic demand is met.

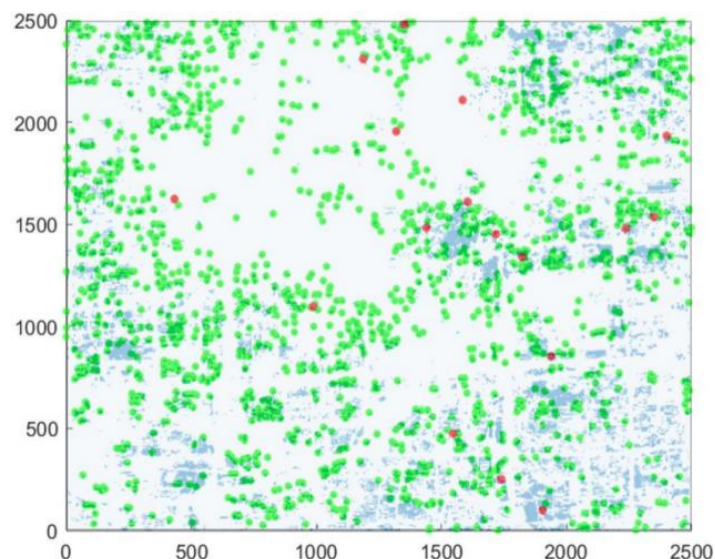


Figure 4. Cover renderings

Base station construction scheme: a total of 17 macro stations, 1,634 micro base stations, the construction cost of base stations is 1,804, the service coverage is 6,351,079, accounting for 90.0% of the total business volume of weak coverage point, meeting the weak coverage business volume requirements of problem 1.

The advantages of the model are that the algorithm is simple, fast calculation speed, and easy to get a better solution. Moreover, since the amount of base station construction in the problem is small compared with the number of nodes in the whole city, the original base station construction planning

results of the model have little impact on the subsequent planning, and the results of the model are reliable.

The disadvantages of the model are that each time a new base station is built, it will have an impact on the feasible domain of the subsequent base station construction. The model adopts the mode of iteration to get the optimal solution. The impact of each base station establishment on subsequent decisions was not taken into account. As the number of iterations increases, previous construction schemes have an increasing influence on subsequent planning. Moreover, the impact of previous construction results on subsequent construction planning will vary with the number of urban nodes and the number of base stations: the construction density of base stations is large, the impact of previous release on subsequent planning will become stronger, and vice versa. Therefore, this model is not suitable for overdone base station construction planning problems.

4. Model building and solution for Problem 2

4.1. Model solution method one

Establishment of the business volume model, objective function:

$$\min\{C = \sum C_i\} \quad (5)$$

Constraint condition

$$W = \sum W_{ij} \geq 0.9W_s \quad (6)$$

$$X_i, Y_i \in Z \cap [0, 2500) \quad (7)$$

$$Q = \{(X, Y) | (X_i - X)^2 + (Y_i - Y)^2 \leq R^2, X \in Z, Y \in Z\}, Q \notin A \quad (8)$$

$$\frac{\pi}{4} \leq \beta \leq \frac{7\pi}{4}, \frac{\pi}{4} \leq \gamma \leq \frac{7\pi}{4}, \frac{\pi}{4} \leq |\gamma - \beta| \leq \frac{7\pi}{4} \quad (9)$$

Table 1. symbol description

Symbol	description
α	local coordinate system variable
β	angle between the 2nd main direction and the 1st main direction
γ	Angle between the 3rd main direction and the 1st main direction
a	Angle between the first principal direction and the ox axis
w_{ij}	The traffic covered by the jth sector of the ith base station
C_i	Cost of the ith base station

If within the circle, the main weak coverage points are not evenly distributed and there are large density differences in each region, the allocated sectors will have a large impact on the subsequent sector distribution. At this time, the allocation of the three sectors should be coordinated, first clustering the weak coverage points in the circle, and then allocating the sector angles. The solution of the model will be better.

In the process of solving, we find out the point Ai1 with the largest traffic within the coverage radius circle of the base station, and take the connection between the base station and Ai1 as the first main direction. After removing the point of the first sector, find the weak coverage point Ai2 with the maximum traffic, and take the connection between the base station and Ai2 as the second main

direction. The third main direction is taken as the reverse extension of the angular bisector of the first and second main directions. After traversing the weak coverage points in the three sectors, it is removed from the feasible region. Perform the second iterative calculation.

Under the Angle constraint of the three main directions, the coordinate constraint of the new base stations and the threshold distance constraint between the base stations, the solution that can meet the business volume is sought.

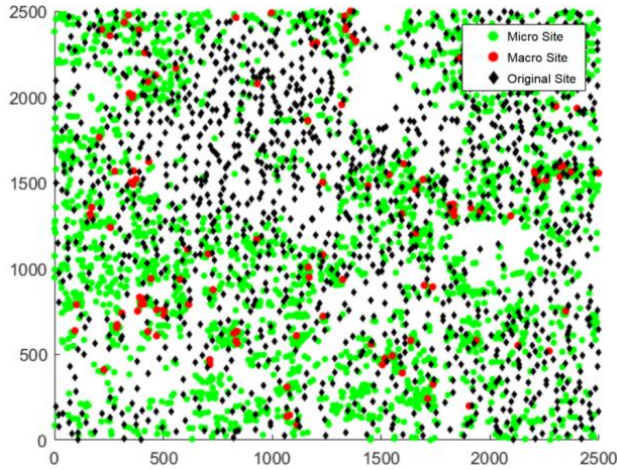


Figure 5. Overall scheme of base station

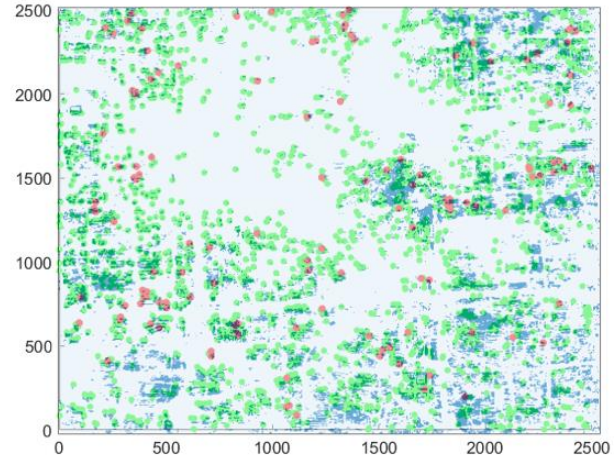


Figure 6. Overlay renderings

Base station construction plan: A total of 127 macro base stations and 2,311 micro base stations were built. The base station construction cost was 3,581, and the achieved service coverage was 6,351,845, accounting for 90.0% of the total service volume of weak coverage points, meeting the service volume coverage requirement of Question 2. Compared with problem 1, the cost increases by 98.6% when the business volume coverage is basically unchanged.

Table 2. Coordinates of some macro base stations

x	y	Total traffic	Sector 1 main direction	Sector 2 main direction	Sector 3 main direction
1369	2351	29844	276.3375446°	156.3429936°	36.34042111°
833	2462	24740	98.53155203°	218.5318326°	338.5321133°
358	1997	24039	165.9629549°	45.96382024°	285.9632355°
1232	1080	31577	233.1307973°	113.1305166°	353.1310779°
163	1318	25204	231.3374394°	111.3428883°	351.33772°

Table 3 Coordinates of some micro base stations

x	y	Total traffic	Sector 1 main direction	Sector 2 main direction	Sector 3 main direction
1356	2271	43295	225.0005261°	105.0002455°	345.0008068°
869	2292	32201	225.0005261°	105.0002455°	345.0008068°
881	1256	33827	0°	120.0002806°	240.0005612°
1096	1658	23715	225.0005261°	105.0002455°	345.0008068°
683	2198	35429	270.0006314°	225.0005261°	67.50015784°

4.2. Model solution method 2

principal direction angle $\alpha, \beta, \gamma \in \left(0, \frac{\pi}{12}, \frac{2\pi}{12}, \frac{3\pi}{12}, \dots, \frac{22\pi}{12}, \frac{23\pi}{12}\right)$. After the construction address is determined, there are only a limited number of combinations of the main directions of the new base station, and there are 1088 options in total, which can be listed in a 1088-row, 3-column matrix

$$angelMat = \begin{pmatrix} \alpha_1 & \beta_1 & \gamma_1 \\ \alpha_2 & \beta_2 & \gamma_2 \\ \vdots & \vdots & \vdots \\ \alpha_{1088} & \beta_{1088} & \gamma_{1088} \end{pmatrix} \quad (10)$$

The base stations are divided into two types: micro base stations and macro base stations. We can use an index to represent a new base station with an established address. If the index is an odd number, a micro base station is established, and the values of the three azimuth angles are (index+1)/2th line of angleMat; If the index is an even number, a macro base station is established, and the values of the three azimuth angles are the index/2th line of angleMat.

The selection method of the new base station construction address is similar to that of the first problem. That is, the weak coverage point with the largest traffic volume is selected as the new base station construction address through iteration each time. Then let the index traverse 1, 2, 3, ... 2176, and select the index with the largest business volume/cost as the final solution.

The model of problem 2 is a modification of the model of problem 1. Under the assumptions, the solution given by the model is the optimal solution because the main weak coverage points are uniformly distributed. The uniform distribution assumption is proposed based on the low distribution density of the main weak coverage points. It greatly simplifies the problem.

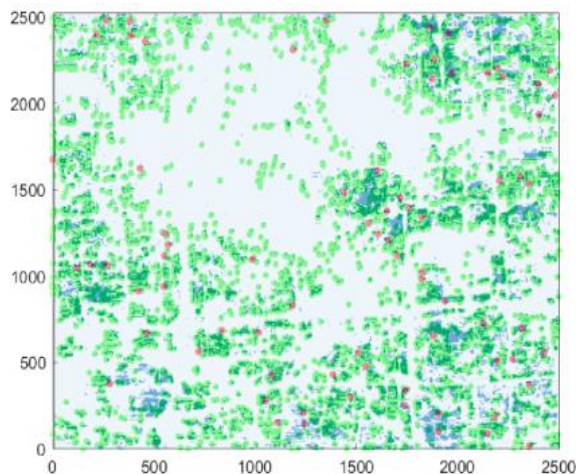


Figure 7. Overall scheme of base station

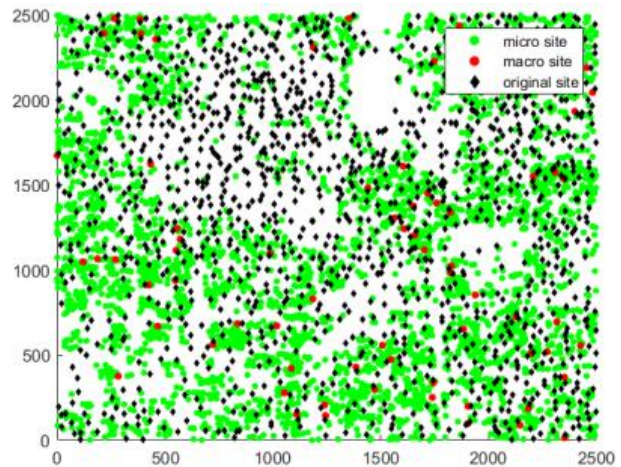


Figure 8. Overlay renderings

Base station construction plan: A total of 75 macro base stations and 3,610 micro base stations were built. The base station construction cost was 4,340, and the achieved service coverage was 6,351,752, accounting for 90.0% of the total service volume of weak coverage points, meeting the service volume coverage requirement of Question 2. Compared with problem 1, the cost increases by 140.7% when the business volume coverage is basically unchanged.

Table 4. Coordinates of some macro base stations

x	y	Total traffic	Sector 1 main direction	Sector 2 main direction	Sector 3 main direction
433	1623	11171.5923	0°	45°	90°
1938	853	12772.5	30°	105°	150°
1604	1610	4452.6	15°	105°	330°
1822	1339	22473.2	0°	45°	90°
2349	1535	4915.8	0°	75°	315°

Table 5. Coordinates of some micro base stations

x	y	Total traffic	Sector 1 main direction	Sector 2 main direction	Sector 3 main direction
1356	2271	43295	0°	45°	90°
567	2017	13074.4	0°	45°	135°
1569	1204	3668.3	0°	75°	255°
1218	1060	34741.4	0°	45°	180°
1731	352	1681.3657	30°	255°	345°

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