

Analysis of greedy algorithm based base station siting search optimization

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Abstract: With the rapid development of 5G technology, the bandwidth of communication is increasing while the coverage of base stations is decreasing. Choosing a site for a mobile network, taking into account the coverage and cost of the base station, is a very challenging issue. When an area has weak coverage, it has an impact not only on the quality of the network, but also on the user experience. Therefore, the clustering of weak coverage points has to be continuously enhanced to facilitate the continuous development of mobile communication technology. This paper firstly establishes the optimization objective of finding large coverage with low station construction cost. Secondly, a greedy algorithm is used to calculate the optimal station site and the optimal sector angle to maximize coverage, taking into account two objective functions: cost and coverage, and to give an optimization scheme for the location of mobile communication network base stations.

Keywords: Base station siting, greedy algorithm, clustering, coverage, optimization scheme

1. Introduction

As mobile communication technology continues to develop, the scale of its application is also expanding. In the field of mobile communication technology, the problem of siting of network stations and the problem of clustering of weak coverage areas are its key research directions. The siting of mobile communication network stations is based on the coverage of the existing network antennas, screening out the weak coverage areas in the region and selecting a certain number of points to establish new base stations. There are two types of base stations: macro base stations, which cover a wider area but are more expensive, and micro base stations, which are less expensive but also less costly. Therefore, in this question, the best way to build a station is to consider the cost and coverage factors. Weak coverage generally means that there is a signal, but the received power of the signal is not strong: an area with $RSRP \leq -100\text{dBm}$ measured by mobile phones is defined as a weak coverage area. The weak coverage points are clustered in areas, and two weak coverage points less than or equal to 20 are clustered into one category and their transferability is considered to better solve the weak coverage problem.

2. Establishment and Solution of Model

2.1. Introduction to the principles of the greedy algorithm

The idea of a greedy algorithm is to construct a feasible solution to a combinatorial optimization problem in a "greedy" manner, without violating the characteristics of the feasible solution in the process. The greedy algorithm is a common method for solving optimization problems, in which the optimal solution is selected at each step of the solution process, provided that the constraints are met, and that each step is independent of the other and does not affect subsequent decisions, thus achieving the desired effect of global optimization from the bottom up.

2.2. Model construction

First, the point with the highest volume of service among the weak coverage points is identified based on the available data, and then, based on the base station cost-performance formula. The cost effectiveness of the macro base station and micro base station at that point is found. Whichever base station is more cost effective, the base station is built. The distance from the existing base station to the new base station (l) is then calculated according to the distance formula between the two points, in

relation to the coverage area of the chosen base station ($d < l$), then it is possible to establish a base station at that location, and if not, then the community at that point. This is a continuous cycle, so that the number of services is accumulated, and the operation is stopped when the coverage of the base stations built can reach 90% of the total number of services. See figure 1.

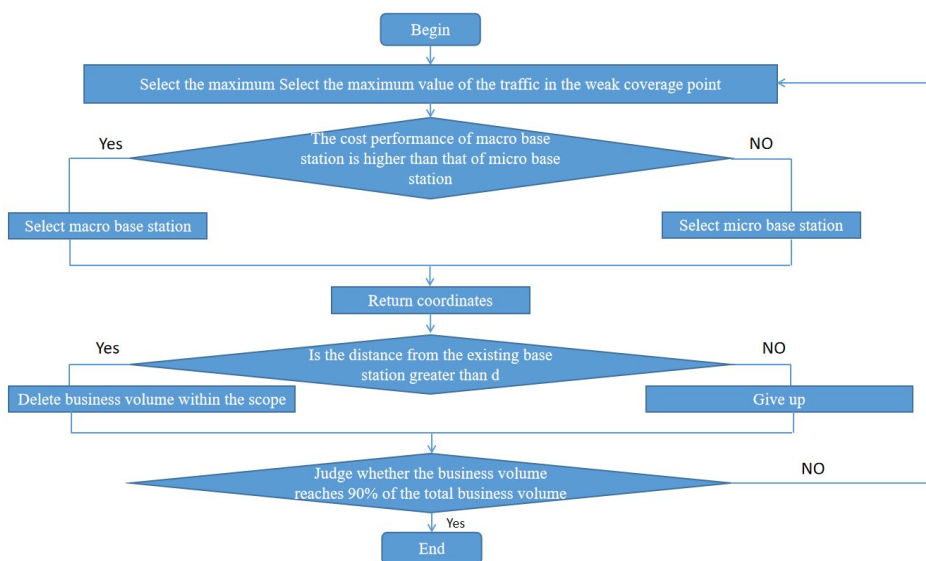


Figure 1: Flowchart of greedy algorithm based site selection optimization

Secondly, the problem of optimal sector orientation has to be considered, so the greedy algorithm is still used on the basis of the aforementioned. In order to make the sector cover the largest possible range of services, we need to make the area covered by the sector as large as possible, and the area covered by the sector is related to the angle of the main direction of the sector, assuming that the angle between the main direction of the sector and the x-axis is θ . Due to the constraints in the topic: the angle between the two main directions should be $\geq 45^\circ$. Since there is a constraint in the question that the angle between the two main directions should be $\geq 45^\circ$ and the sector coverage cannot be covered if it exceeds 60° , the coverage may not reach 90%. In this case, the sector angle needs to be changed. First, look at the solution for the three sectors of a single base station. The first sector angle is obtained by rotating the rhombus-like shape by 360° in 5° increments with (x', y') as the centre, finding a position where the weak coverage point has the maximum amount of service, selecting the weak coverage points contained in that position and recording the sum of their service volumes. Then, the first sector is removed and the first sector is rotated by 270° in 5° increments, with (x', y') as the centre, to select the second sector direction of the base station. Finally, excluding the first and second sectors outside the 45° range, the rhombus is rotated 180° by 5° to the centre of (x', y') to select the third sector of the base station, and the angles of the three sectors of all base stations can be found. See figure 2.

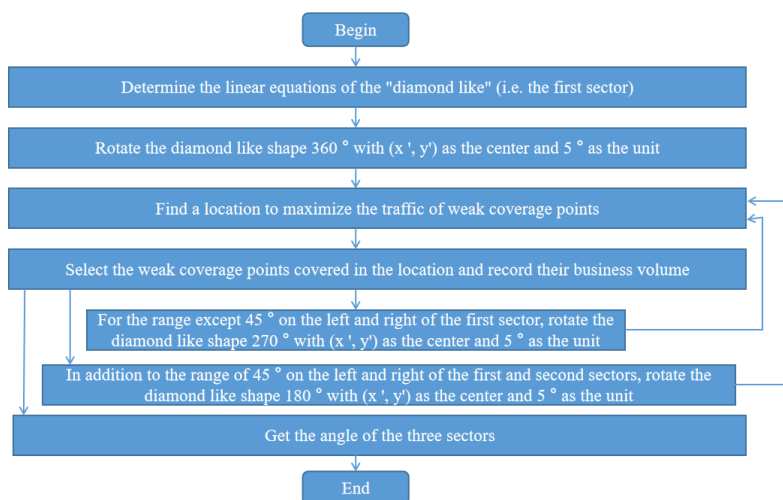


Figure 2: Flowchart of the optimization selection process for each base station

Using a holistic approach, the linear equations for all base stations are determined and then the angle of the first sector of all base stations is found to maximize the amount of service at the weak coverage point. The angle of the first sector selected is solved in Python to obtain the angle of the second sector of all the base stations, then all the weak coverage points that can be included in the base station are calculated and the sum of the services of all the weak coverage points is recorded. The selected first and second sectors are then brought into Python to give the angle of the third sector of all base stations and the sum of the services for all weak coverage points. Then the traffic from all the weak coverage points is summed and divided by the total traffic of all the weak coverage points, A , to find the coverage ratio required in the question. See figure 3.

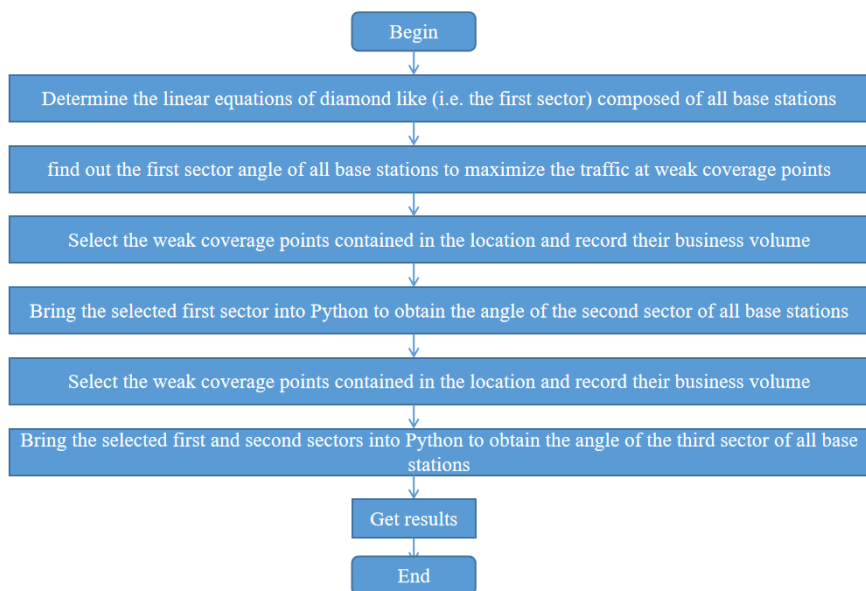


Figure 3: Flow chart of the overall idea

3. Model Evaluation and Analysis

3.1. station siting search optimization

A heat map was created to visualize the given data, i.e. the heat map was used to show the business volume in the weak coverage area. In order to have a better view of the specific base station coverage, the weak coverage raster data and the coordinates of the existing site are put into the same diagram, through which the coverage of the existing base stations and the areas with missing signal coverage can be visualized more intuitively (blue dots indicate the existing site, orange indicates the weak coverage areas) See figure 4.

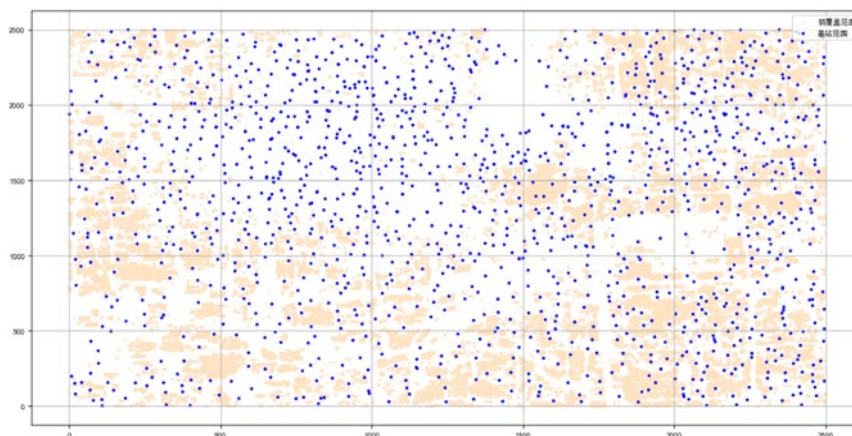


Figure 4: Data fit of existing base stations and weak coverage areas

Considering the large span of data and the uneven structure, heat maps with different upper limits (1, 10 and 50 respectively) are made to reflect the business volume visually and to enhance visualization. See figure 5, 6, 7.

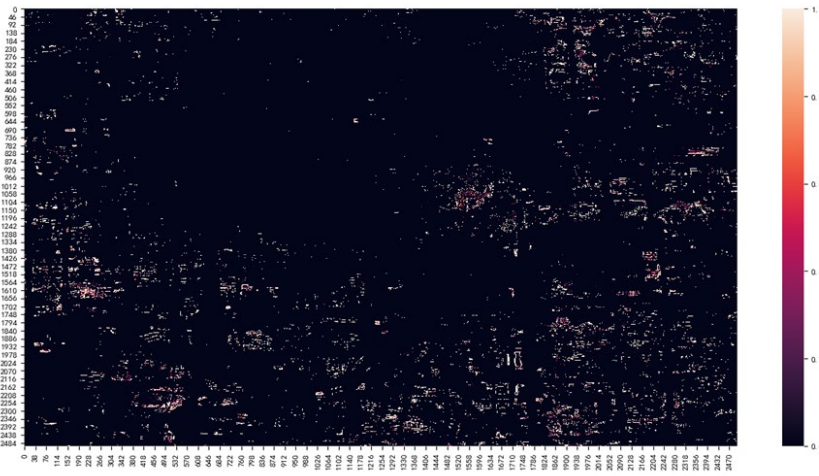


Figure 5: Heat map of service volume at weak coverage points with a cap of 1

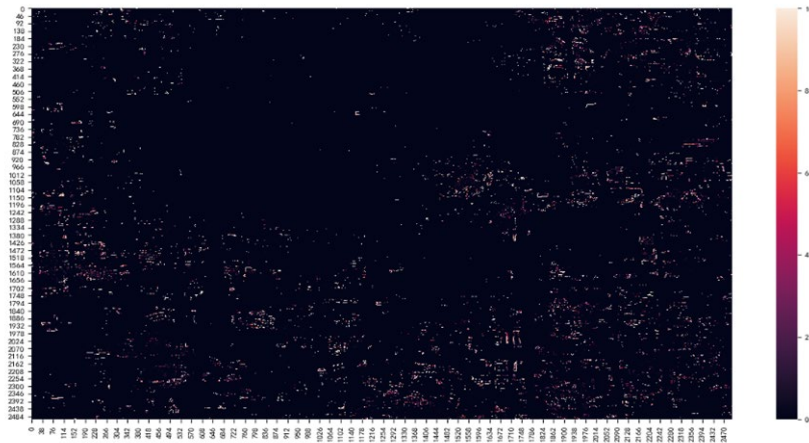


Figure 6: Heat map of business volume at weak coverage points with an upper limit of 10

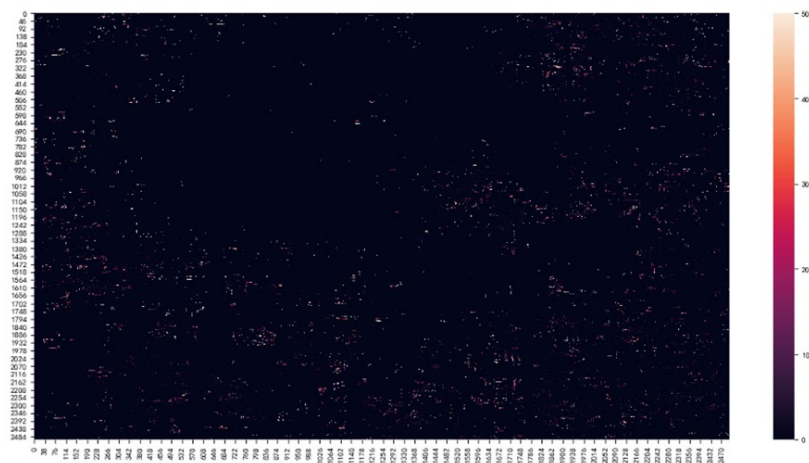


Figure 7: Heat map of business volume at weak coverage points with an upper limit of 50

For this problem, two objectives (one is coverage and the other is the cost of setting up the base station) have to be taken into account, and to better address both objectives, the parameter "base station cost effectiveness" (the ratio of the cost required to set up the base station to the amount of services it

can satisfy, In the analysis of the topic, the sum of the weak coverage areas of the base station ($\alpha=182807$), the sum of the traffic ($A=7056230$), the traffic at each weak coverage point (η), the coordinates of the current site (P_0) and the traffic at the lowest weak coverage point ε (90% of the total traffic) can be derived. It is difficult and unrealistic to achieve complete coverage of $2500 * 2500$ points.

However, it is important to take into account the "liveability indicator" in practice, i.e. that the areas with the highest traffic are covered by the base stations as much as possible. Therefore, a greedy algorithm can be used to find out which of the weak coverage points have the highest business volume and assume that a macro base station and a micro base station will be built there. Also, after determining what kind of base station to build, consider the constraint in the question: $\|P-P_0\|_2 \leq d$. Based on this, determine whether a base station can be built at that point, and if so, keep the data, if not, discard the data. If the data is retained, all the weak coverage points within the coverage area of the base station are identified according to the coverage area of the base station, and the total service volume of all weak coverage points is calculated. From the remaining data, the point with the highest volume of services is selected, and the greedy algorithm is used to add up the volumes of the weak coverage points until the sum of the volumes of all weak coverage points reaches ε . The algorithm ends and the result is obtained. The problem is ultimately solved in Python by deriving the coordinates of the relevant points and then deriving l from the equation for the coordinates between the two points.

$$l = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2} \tag{1}$$

The distance between the two points can be calculated as a function of $d < l$, which satisfies the conditions for establishing a base station, so a micro-base station can be established at this location. The Python calculations resulted in a total of 42 macro base stations and 319 micro base stations. In practice, the coverage area of the base station is not completely circular, but decreases linearly along the main direction to the left and right, which results in a "rhombus like" sector shape. See figure 8.

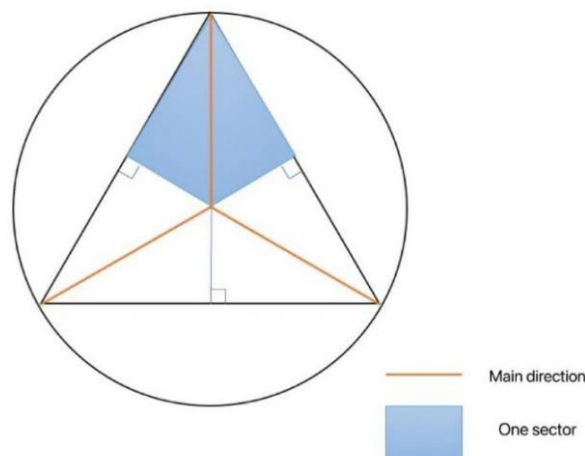


Figure 8: Sector principal directions and 'rhombus-like' representation

According to the simulation algorithm thinking, starting from a certain direction along a certain direction increase 5° , by Python analysis can be seen, in a certain area of the sector can cover the weak coverage point of the service first increasing, when increased to a certain extent, the sector can cover the weak coverage point of the service will be decreasing, so at a certain time there is a certain angle so that the sector can cover the weak coverage point of the service has The maximum value. To keep the Python algorithm simple, holistic thinking is used. The direction of the first sector of all base stations is determined, then all base stations are brought into the algorithm to find the direction of the second sector, and similarly the direction of the third sector, and then this maximum value is found using Python, which is the solution to the problem. The first problem is to make the sector cover as large an area as possible on the basis of 60° to the left and right of the main direction of the sector. From the problem, we can see that the two angles of the sector are right angles, one angle is 120° , from the geometric relationship can be obtained The angles of the extensions of the four sides of the out sector to the x-axis are $60^\circ-\theta$, $30^\circ+\theta$, $150^\circ-\theta$ and $210^\circ-\theta$. See figure 9.

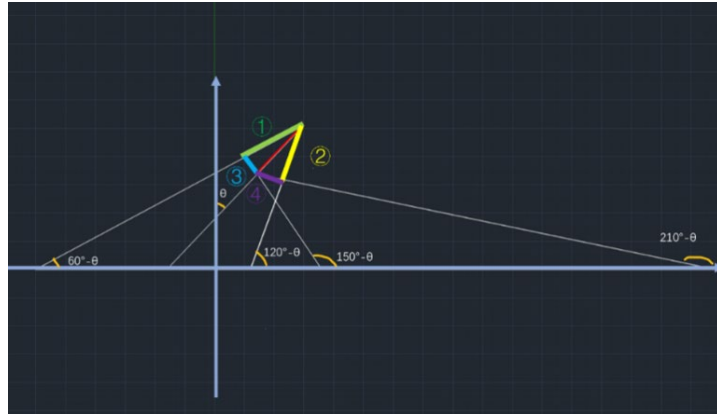


Figure 9: Schematic diagram of the coverage of a sector

Because the four sides of the sector, ③ and ④, pass through the centre of the base station, and the slope is equal to the tangent of the angle between the extensions of ③ and ④ and the x-axis, the equation of the lines ③ and ④ can be found.

$$y_3 \geq (\tan \frac{5}{6}\pi - \theta)x + b_3 \quad (2)$$

$$y_4 \geq (\tan \frac{7}{6}\pi - \theta)x + b_4 \quad (3)$$

The point (x', y') is then found using the method of polar coordinates. See figure 10.

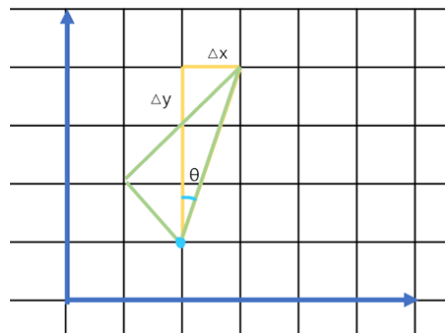


Figure 10: Schematic diagram of the polar coordinate method

Then, by the same token, the equations for ① and ② can be derived from the slopes

$$y'_1 \leq (\tan \frac{\pi}{3} - \theta)x' + b_1 \quad (4)$$

$$y'_2 \leq (\tan \frac{2}{3}\pi - \theta)x' + b_2 \quad (5)$$

The system of linear equations for the sector can then be listed as follows.

$$y_3 \geq (\tan \frac{5}{6}\pi - \theta)x + b_3 \quad (3)$$

$$y_4 \geq (\tan \frac{7}{6}\pi - \theta)x + b_4 \quad (4)$$

$$y'_1 \leq (\tan \frac{\pi}{3} - \theta)x' + b_1 \quad (5)$$

$$y'_2 \leq (\tan \frac{2}{3}\pi - \theta)x' + b_2 \quad (6)$$

The analysis carried out by the Python software shows that of the 42 macro base stations and 319 micro base stations, the numbering starts from 0 and is 360 in total.

4. Conclusion

(1) The model and algorithm can find the local optimal solution relatively quickly and can take into account multiple objectives: to make the amount of services covered by the base station as large as possible, the cost of setting up the base station as low as possible and the "livability index" as high as possible.

(2) The model introduces new terms such as "livability index", "coverage" and "cost effectiveness of base stations", and is based on a heat map to enhance the visualization and innovation of the model. The model is based on a heat map, which enhances the visualization and innovative thinking of the model.

(3) The calculations for the model are based on Python calculations, a widely used high-level, general-purpose programming language, and the accuracy of the results is high, which can better meet the actual status quo.

(4) The model is comprehensive in the issues it considers, e.g. sector specific coverage, aggregation of weak coverage points, etc., and has strong practicality.

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