Research on Communication Site Planning and Regional Clustering Based on Optimal Multivariate Optimization Model

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Abstract. In recent years, in the context of the continuous development of 5G networks, the construction of mobile communication mobile base stations is extremely important for the overall network environment construction in my country. The sites in the objective function are planned multiple times through the immune genetic algorithm, and finally the optimal site is re-planned and the weak coverage points are clustered.

Keywords: Optimal multivariate model, simulated annealing algorithm, immune genetic algorithm, K-means clustering algorithm, DBSCAN density clustering algorithm class algorithm

1. Introduction

The 5G network requires that the distance between each base station be shortened, and the connectivity, stability of each mobile communication system, and the coverage rate of mobile communication in various regions are difficult to coordinate with each other [1-3]. To this end, by simulating the planning of the coverage and cost of the existing base station and the new base station, the optimal site selection scheme is selected, in order to solve the coverage problem of the weak coverage area of the existing network, and at the same time control the cost [4-6]. The basic processing method to solve the problem of mobile communication site planning optimization scheme is to solve the multi-variable optimization model, usually using optimization algorithms in different situations and optimize the model based on this [7,8]. Choose to build a multivariate optimization model, and use matlab to solve the objective function using the simulated annealing algorithm [9]. Using the immune genetic algorithm, the established function is solved again within the new constraints. The three main directions are clustered by using the phylogenetic clustering algorithm. Categorize the optimal situation, and obtain the optimal solution of the angle in each direction [10].

2. Construction and Solution of Optimal Multivariate Optimization Model

2.1. Preparation before model building

Consider the base station coverage as a circular area with a radius of 30 or 10, as shown in Figure 1. The coverage is required to be three sectors, and the coverage distance in the main direction is 30 or 10. The coverage is reduced linearly, and it is reduced to 15 or 5 at 60°. When the area exceeds 60°, the sector cannot cover, as shown in Figure 2.

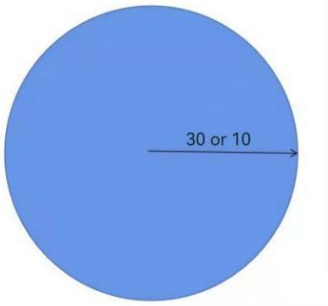


Figure 1 Original base station coverage

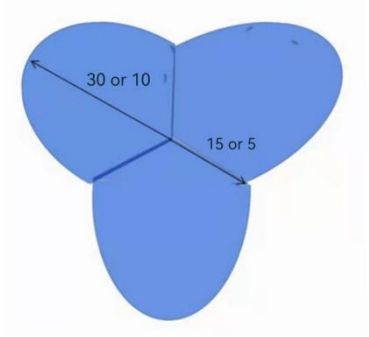


Figure 2 Base station coverage under constraints (main direction 120° case)

And Figure 2 shows the case where the included angle between the main directions of the three sectors in a base station is 120°. In other cases, the main directions of the three sectors are the included angle can be changed arbitrarily, but not less than 45°.

2.2. Model establishment

After the base station coverage angle constraint is added, at this time, the coverage area of the base station under the constraint condition is reduced compared to the coverage area of the original base station. Therefore, we add constraints:

Constraint 1: The coverage of the base station is changed to three sectors.

$$MAXS_{macro} = 506.25\sqrt{3} \cdot \pi \tag{1}$$

$$MAXS_{micro} = 56.25\sqrt{3} \cdot \pi \tag{2}$$

Constraint 2: The included angle between the main directions of any two sectors should be greater than 45°

$$\theta_1 - \theta_2 \geq 45° \tag{3}$$

$$\theta_1 - \theta_3 \geq 45° \tag{4}$$

$$\theta_2 - \theta_3 \geq 45° \tag{5}$$

According to the above objective function and constraints, we establish the following model:

Objective function:

$$Optimal = (MAXS_{macro} \cdot \theta/180 + MAXS_{micro} \cdot \theta/180) \cdot 3 + (10X + Y) \tag{6}$$

Restrictions：

$$\text{s.t} \begin{cases} Di - 10 > 0 \\ \|P - P_0\| = \sqrt{(x - x_0) - (y - y_0)} \leq 30 or 10 \\ (900\pi \cdot X + 100\pi \cdot Y) \cdot Si \geq 90\% \\ MAXS_{\text{macro}} = 506.25\sqrt{3} \cdot \pi \\ MAXS_{\text{micro}} = 56.25\sqrt{3} \cdot \pi \\ \theta_1 - \theta_2 \geq 45^{\circ} \\ \theta_1 - \theta_3 \geq 45^{\circ} \\ \theta_2 - \theta_3 \geq 45^{\circ} \end{cases} \tag{7}$$

Among them, $MAXS_{macro}$ —the maximum area that the macro base station can cover; $MAXS_{micro}$—the maximum area that the micro base station can cover; θ_i—the included angle between the main directions of any two sectors.

The coverage area of the base station changes, and the three sectors can be rotated under certain conditions to achieve coverage of weak coverage areas. Although the sector rotation increases the flexibility of site coverage, the overall coverage is reduced, while the rotation angle of the sector needs to be substituted into various constraints, and the site planning is analyzed in combination with the model.

2.3. Solving the model

Based on the optimized new model, the ratio of the coverage of the new base station (consisting of three sectors with variable primary direction) to the coverage of the original base station, i.e., the maximum coverage of the macro and micro base stations, is further solved. The coverage area is 97.4% of the original coverage area. After changing the coverage range, some of the BTSs in the mid-planned sites cannot cover the weak coverage points, resulting in a decrease in traffic level, which may be lower than 90%. At this point, we analyze the objective function with an immune genetic algorithm and the constraint is solved again. While analyzing the new site planning, the solution of the simulated annealing algorithm is verified to be correct.

The process of the immunogenetic algorithm is shown in Figure 3. Based on the natural selection and inheritance principles of Darwinian evolution, the solution is made into a population of coded genetic individuals. After the primary population is generated, the population that does not meet the affinity requirement is genetically crossed and mutated according to the principle of survival of the fittest in simulated nature, and then an immune factor is added to select antibodies for it. The suppression operation is performed and a new population that is "more adapted to the environment" is generated, i.e. an approximate solution that is closer to the requirements of the problem. This is substituted into the second model, i.e., by planning multiple times for the sites in the objective function and eventually finding the optimal planning coordinates.

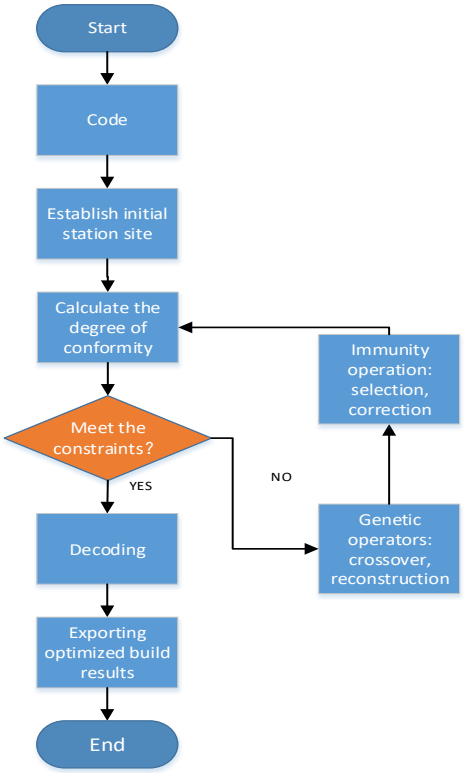


Figure 3 Immune Genetic Algorithm Process

According to the above algorithm flow idea, matlab programming is used to solve the objective function. We select some base stations in the area of coordinates (0,0) - (1000,1000) as examples, and solve the weak coverage point in the case of the lowest cost. The maximum amount of business that can be achieved. Example weak coverage point coordinates are shown in Table 1.

Table 1 Example weak coverage point for model two

X	Y	X	Y	X	Y
122	848	710	874	287	881
211	848	757	874	353	881
339	848	609	237	626	279
340	848	611	237	388	279
341	848	157	875	389	279
342	848	760	875	433	593
563	848	861	875	771	593
564	848	996	557	171	917
565	848	742	558	784	917
566	848	951	558	310	594
567	848	551	238	293	594
124	210	918	238	276	918
310	210	709	876	611	281
497	210	756	876	171	842
975	210	863	876	308	919
970	210	550	239	313	919
122	849	672	239	511	919
216	849	273	877	309	204
217	849	758	877	163	921
218	849	861	877	266	921
219	849	862	877	441	385
136	211	754	560	675	72
22	848	861	560	526	356
605	764	941	560	421	762
430	764	831	240	673	146
341	848	694	240	606	763
71	764	705	878	586	847
497	210	759	878	567	806
671	147	868	878	960	805
976	210	200	700	606	805
563	849	164	879	986	804
62	147	246	879	872	803
218	849	320	879	986	803
136	211	323	879	989	802
54	533	510	242	801	556
403	533	754	561	996	556
239	850	306	880	493	234
145	213	306	880	163	874
498	213	323	880	708	874
409	534	950	562	443	597
156	214	158	881	197	881

From the solution result obtained by the immune genetic algorithm, it can be seen that the weak coverage point selected in this problem can increase the traffic coverage after the site is rebuilt. Adding about 15017, the coverage reaches 87.4% compared to before planning. The solution results and the number of iterations is shown in Figures 4 and 5.

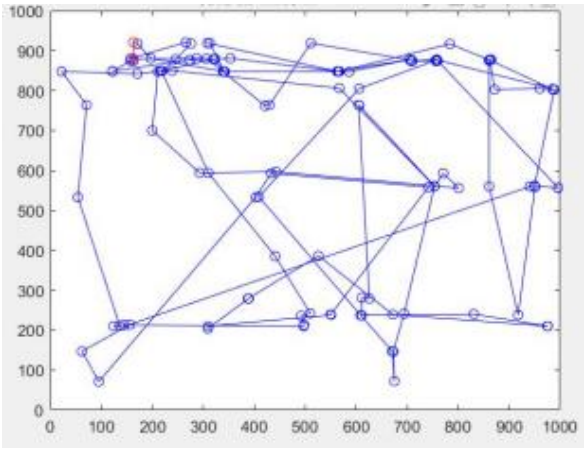


Figure 4 New site after immune genetics

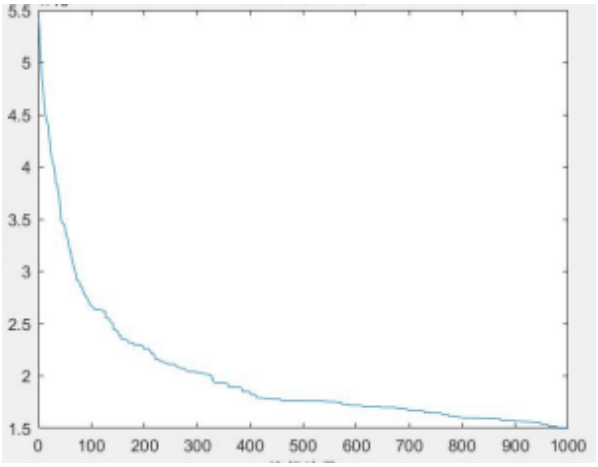


Figure 5 The number of iterations of the station building algorithm

The sector angle problem is related to the surrounding conditions of the new site. According to the objective function under the constraints, it can be obtained: Under the circumstance, the angle between the main directions of each sector is 120°, which is the best angle, because it can cover the surrounding area to the maximum extent. If the distance between the original base station in the border area and the main direction range of the sector is within the threshold value, it does not meet the constraints, that is, the angle between the sectors should be adjusted.

After the coverage changes, the previously established site cannot meet the requirement of 90% of the traffic in the weak coverage point being covered, so we plan and rebuild the site. When planning reconstruction, the angle of each sector in each base station should be considered in the model, and the factors that affect the angle distribution of sectors are: Therefore, we plan to rebuild the site. When planning reconstruction, the angle of each sector in each base station should be considered in the model, and the impact of the factors of sector angle distribution are:

1. Whether the distance between the surrounding base stations and the new base station is greater than the threshold value.

2. What is the angle that can maximize the coverage of the business volume.

3. After the angle changes, whether the sector coverage can cover the weak coverage point before the change.

Finally, the system clustering method will be used to perform cluster analysis on the angles of the three main directions. First, the angles of the two main directions will be calculated, and the optimal cases are combined into one category, the angle between the category and the other direction is calculated again, and the optimal cases are combined into one category, and finally each category will be obtained. The optimal case of the direction angle, as shown in Figure 6.

Iterative history records

Changes of cluster centers

iteration	1	2	3	4	5	6	7	8	9	10
1	44.349	177.433	263.882	261.355	209.200	261.667	218.932	215.111	122.086	211.662
2	25.289	64.867	64.859	40.241	70.090	21.657	107.392	68.614	39.374	58.841
3	9.930	36.653	32.788	35.775	43.702	16.823	48.368	26.546	30.241	44.425
4	16.032	23.878	16.348	20.300	18.493	7.787	31.644	28.568	17.623	21.225
5	7.106	13.427	7.709	21.231	15.508	7.059	15.474	19.221	16.408	8.765
6	9.755	2.264	4.176	16.978	2.431	.000	13.068	12.709	17.840	.000
7	2.603	.000	12.953	6.897	1.751	.000	23.087	19.055	12.319	.000
8	2.042	2.149	4.113	1.687	1.661	.000	12.078	11.786	2.243	.000
9	2.527	2.096	.000	.000	.000	.000	5.462	7.055	.000	2.659
10	2.598	3.503	.000	.000	.000	.000	.000	3.593	.000	4.289

Figure 6 Systematic cluster analysis of included angles of each sector

Taking the example weak coverage point of model 2 as an example, the variation of the sector angle of the newly built site around it varies with the number of iterations. The angle value is shown in the figure above. After cluster analysis and re-planning, the main direction of each base station reaches 91.47% of the traffic at the weak coverage point. The distribution is shown in Figure 7:

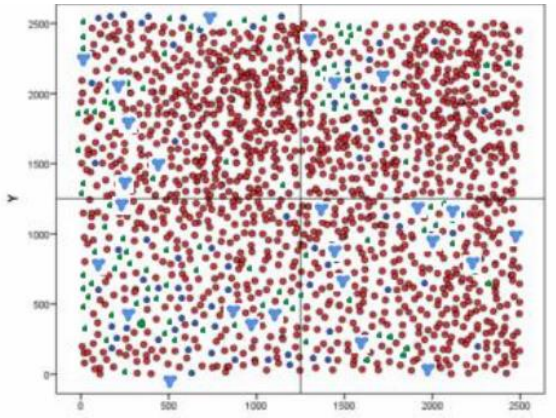


Figure 7 New site planning

3. Establishment and Solution of Density Clustering Model Based on K-means and DBSCAN

3.1. Selection of Clustering Algorithms

In order to better solve the problem of weak coverage, it is necessary to perform regional clustering on the known weak coverage points, and group the weak coverage points with close distances into a group to obtain weak coverage areas, so as to manage and solve the problem of weak coverage separately. In the known weak coverage area, re-clustering is performed according to the difference of the total signal strength of the area to obtain the degree of lack of signals in each area, that is, the X, Y and signal strength of the weak coverage area are three-dimensionally clustered, so as to be able to Better solve the weak coverage problem.

First, this question uses the K-means clustering algorithm to perform two-dimensional clustering on X and Y respectively, and then perform three-dimensional clustering on X, Y, business volume coverage, etc. The results are shown in Figures 8 and 9 respectively.

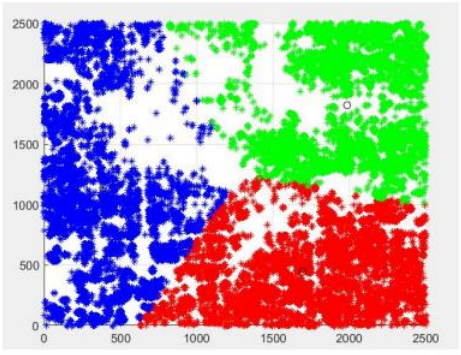


Figure 8 4 K-means 2D cluster plot

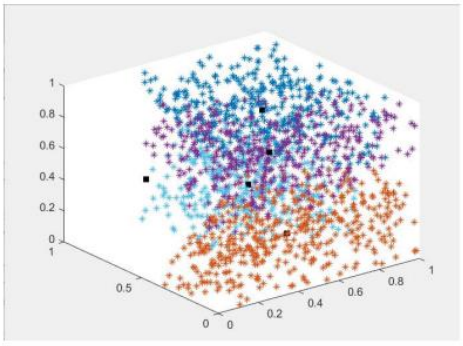


Figure 9 K-means 3D clustering

In order to compare whether the algorithm complexity of the K-means clustering method is small, by using the DBSCAN clustering method again to perform cluster analysis on the weak coverage points after denoising points, clusters of any shape can be scanned, which is similar to the K-means clustering method. Unlike Means, it is generally only used for convex sample set clustering. At the same time, the DBSCAN algorithm can also find outliers while clustering, and is not sensitive to the outliers in the dataset. Because the data to be processed is relatively dense, the DBSCAN density clustering algorithm can ensure the accuracy of the results while ensuring the integrity of the data, and significantly improve the clustering effect of weak coverage points, so the DBSCAN clustering algorithm can better realize the problem requirements.
Its algorithm flow is shown in Figure 10.

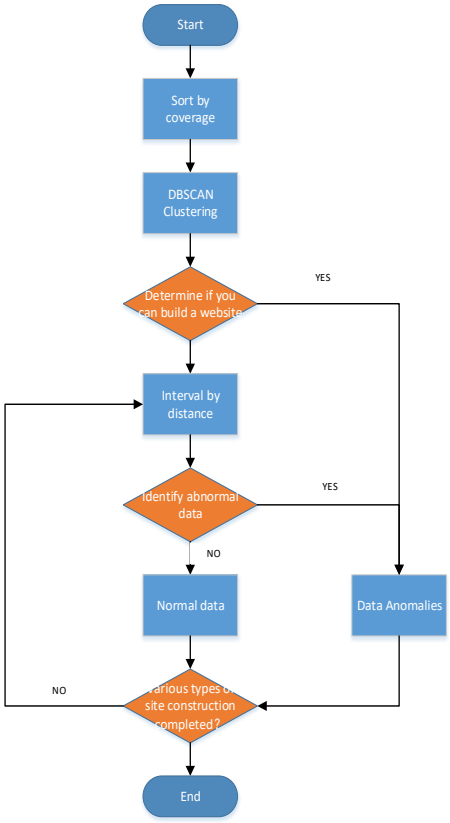


Figure 10 DBSCAN clustering algorithm

3.2. Analysis of clustering results

According to the requirements, the data is first processed. Table 2 shows some samples whose distance is less than 20.

Table 2 Sample point example

x	y	volume of business	distance
1	1883	2.531582	14
1	1897	5.508241	1
1	2495	79.592041	1
1	2496	89.222649	1
1	2497	52.79237	1
2	763	5.712186	7
2	770	4.595236	1
2	771	4.388606	1
2	772	6.381247	1

After performing DBSCAN density cluster analysis on the above samples, the results are shown in Figure 11.

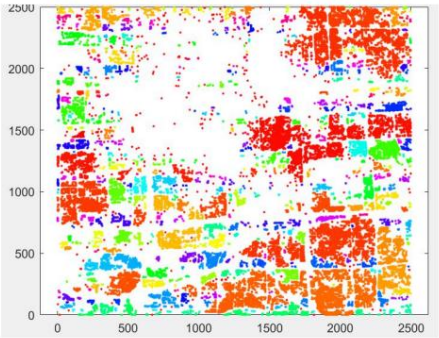


Figure 11 DBSCAN density cluster analysis results

The K-means clustering algorithm is used to perform two-dimensional clustering analysis and three-dimensional clustering analysis on the weak coverage points, and the DBSCAN density clustering algorithm is used to perform clustering analysis on the weak coverage points. The clustering results of the algorithm, and its cluster centers and iterations are obtained, as shown in Figure 12, and the data results show that the total time complexity of the DBSCAN density clustering algorithm is lower.

initial clustering center

clustering

	1	2	3	4	5	6	7	8	9	10
x	1474.00	2395.00	2461.00	1.00	869.00	2107.00	41.00	1113.00	585.00	1832.00
y	1517.00	1783.00	892.00	1938.00	2347.00	3.00	155.00	170.00	1051.00	2472.00

Final clustering center

clustering

	1	2	3	4	5	6	7	8	9	10
x	1429.06	2119.27	2119.40	358.11	1024.33	2128.32	455.37	1271.65	605.65	2072.49
y	1438.80	1698.22	910.69	2026.02	2089.89	292.65	330.65	545.35	1274.77	2241.76

Figure 12 Partial clustering results

4. Conclusion

The simulated annealing algorithm has high operating efficiency, can better solve the mathematical model we established, and has a better way of dealing with constraints. The immune genetic algorithm can perform random and iterative searches until the global optimal solution is found, which is extremely beneficial to the site planning problem. The DBSCAN density clustering algorithm has great advantages in dealing with dense data. It can ensure the accuracy of the results while ensuring the integrity of the data, and significantly improve the clustering effect of weak coverage points. However, the main genetic operators of the immune genetic algorithm are all under the condition of a certain probability of occurrence, and may also degenerate while providing optimization opportunities. Therefore, duplicate and wrong sites will be selected, resulting in a large time complexity. The simulated annealing algorithm may always process the local optimal solution and cannot jump out to the global optimal solution.

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