Genetic Algorithm Based Method for Signal Channel Allocation of Mobile Base Station Optimization

Yida Yan*
Beijing Jiaotong University, China

*Corresponding author e-mail: 18231630@bjtu.edu.cn

Abstract. Signal frequency band allocation is a crucial task in mobile communication. In realistic, the frequency resources that can be used to realize communication are relatively scarce. There are signal frequency interference problems between adjacent base stations. Existing frequency band resource allocation method try to find the best allocation program by visiting every node to search local optimal allocation program for each station. However, existing method is computationally complex. In this paper, we propose a global optimization model and solving the problem based on genetic algorithm. Finally, we test on an example to demonstrate the effectiveness the proposed method.

Keywords: Frequency channel allocation, genetic algorithm, coding, co-channel interference, adjacent channel interference

1. Introduction
With the rapid development of mobile communication technology, the frequency channel allocation of mobile signal base station has become an inevitable topic. The channel allocation of mobile communication base station is to allocate the limited communication frequency resources to each base station in a certain space, so as to avoid the co-channel interference and adjacent channel interference. The available signal channel of mobile communication base station is limited, and the coverage of each base station is also limited. Therefore, we will set up many base stations to ensure the communication in a certain area. In the process of using the base station, it is necessary to allocate the communication frequency of the base station. The same frequency interference of the same signal frequency in the same base station and the adjacent frequency interference in the same base station should be considered in frequency signal allocation. In a certain region, there are some interference mobile communication base stations evenly distributed. The frequency of mobile communication signal is divided into limited frequency bands. In the process of frequency allocation, there will be interference between different frequency signals in the same base station. There will also be some interference between adjacent base stations. Therefore, when allocating the signal frequency used by the base stations in the same region, it is necessary to avoid mutual interference between the signals as far as possible, so as to ensure the authenticity of the received and transmitted signals.

With the popularization of mobile communication terminals (mobile phones, IPDA, tablet computers, etc.), it has brought great pressure to the construction of mobile communication facilities. On the one hand, more communication base station construction can effectively alleviate the pressure...
brought by the rapid growth of communication demand. At the same time, the efficient signal frequency distribution technology can make the limited communication equipment play the maximum effect, so as to ease the communication pressure. Therefore, the research of mobile base station signal distribution technology is of great significance for the development of mobile communication technology. It is the key technology to ensure human production activities and information exchange, and has a wide application prospect.

However, the existing mobile communication signal frequency channel allocation optimization research is less. It is lack of effective theoretical basis. In addition, there is no unified evaluation method for signal frequency allocation optimization. The optimization problem of signal frequency allocation is a linear programming problem. Considering the same frequency interference and the near frequency interference, the signal allocation of a base station needs to consider the signal allocation of several adjacent base stations at the same time. The complex constraints make it difficult to solve the problem.

In this paper, we propose a global optimization model for signal frequency channel allocation of mobile communication base station. Instead of visiting nodes for each base station, we build relationship of neighborhood station and neighborhoods’ neighborhood station. The co-channel interference and adjacent channel interference is formulated to be the constraints of the optimization model. And we transform the constraints to penalty items for best solution searching. Finally, the genetic algorithm is used to solve the optimization model and the effectiveness is proved on a example.

2. Related Work

The problem of base station frequency allocation is a typical optimal digital distribution strategy task. Some scholars have established a model by greedy algorithm and graph theory, and achieved the base station frequency allocation under the restriction of setting the relevant parameters [1]. In contrast, we consider each base station ratio can be regarded as an individual in the population by genetic algorithm, and the signal allocation of different frequencies of base stations can be equivalent to different genotypes. The optimal allocation of base station frequencies can be calculated through the genetic changes of various behaviors in the population and the conditional restrictions.

Wang et. al. [2] proposed a method based on hierarchical genetic algorithm to achieve the optimal number allocation, which effectively improved the basic genetic algorithm with premature convergence defects. However, their work study on the frequency problem with the number of channels allocated to each station fixed. And Existing method mainly focus on find the solution which satisfies the co-channel interference and adjacent channel interference. They didn’t consider the usage of the frequency resources.

Zhu et al. [3] studied the frequency assignment of each wayside base station in underground wireless communication network. In their research work, they aims to reduce interference and improve network throughput. To solve this problem, they proposed a frequency allocation strategy of underground base station based on weighted conflict model.

Yin et al. [4] studied on the resource allocation and based station placement task. They worked on the UAV-assisted downlink cellular network. In their work, the UAV is treated as an aerial base station. Then the resource allocation and base station placement problem is studied. They proposed an optimization model of two resources sharing method to maximize the throughput.

Genetic algorithm is an efficient method for resources allocation problem [5-10]. Kaveh et al. [5] studied on the hospital location problem. They proposed a novel method which improved the traditional genetic algorithm by utilizing the effectiveness and affectability to combine the chromosomes. Gomes et al. [5] studied on the optimal Lidar location problem. They proposed an improved genetic algorithm by formulating a domain-specific objective function to evaluate the fitness of each individual.
3. Method

3.1. Formulation of Signal Channel Allocation of Mobile Communication Base Station

Signal channel allocation of base station is an important problem in the development of mobile communication. Especially with the popularity of mobile phones and other mobile terminals, the user data transmission traffic is growing rapidly, the existing spectrum resources cannot meet the growing demand, and the mobile communication service is facing great pressure. In practice, due to the limitation of technology level and external environment on the attenuation of radio wave propagation ability, the available communication frequency resources are very limited. Different from the traditional material mineral resources, spectrum resources can be reused for many times without loss. Mobile communication carries out signal transmission through communication base station, and each base station covers a certain area. In the process of mobile communication, the number of base station signal frequency in each area is limited, and the use of frequency also faces the problem of signal interference. However, it is worth noting that improper frequency resource allocation will cause signal interference. Therefore, it is necessary to allocate the working frequency resources of each base station scientifically and reasonably. Mobile communication system is faced with two kinds of interference, intra network interference and extra-network interference. This paper focuses on the optimization of intra network interference.

Intra network interference of mobile communication base station refers to the mutual interference between signal frequencies in radio communication system, including co frequency interference and adjacent frequency interference. Co frequency interference refers to the problem that the frequency of interference signal is the same as that of useful signal, and interference signal causes interference to the reception of useful signal. In the mobile communication network, through the coverage of mobile communication base station, the region is divided into a grid like small area. In the mobile communication system, when the carrier interference ratio SINR caused by the same frequency interference is less than a certain threshold, the call effect of the user can not be guaranteed, and the communication terminal and normal call cannot be established. Adjacent frequency interference refers to the interference between radio signals with close frequency when they enter the receiving equipment. Therefore, in order to reduce the influence of intra network interference, the frequency allocation of communication base station needs to meet the following constraints:

1. The frequencies allocated in the same base station cannot be the same and cannot be adjacent.
2. The frequency allocated in any base station cannot be the same as that allocated in adjacent base stations and cannot be adjacent.
3. The frequency allocated in any base station cannot be the same as that allocated in adjacent base stations of adjacent base stations;

In addition, the available frequency resources of operators are limited. In order to ensure the normal operation of each base station, the number of frequency resources allocated in each base station cannot be too small or too much.

Suppose we allocate frequency resources to base stations in area A. Area A is divided into small square areas with $m$ rows and $n$ columns at equal intervals, and the center point of each small square area is assumed to have a mobile communication base station (as shown in Fig. 1). The red square denotes the target station. The co-channel interference and adjacent channel interference will be described on the relationship between the target station and the neighbor stations (in green) or the relationship between the target station and the neighbor’s neighbor stations (in blue).
Define the set \( f = (f_1, f_2, \ldots, f_k) \) denotes all the frequency channels could be used. That is to say, we allocate limited number of frequency channels to each station from all the \( k \) channels in set \( f \). Let \( A_{x, y, z} = \{x_{ij}\} \) denotes the allocation program for all stations in area \( A \). \( x_{ij} = (x_{ij1}, x_{ij2}, \ldots, x_{ijk}) \) is an 0-1 binary vector. It denotes the allocation program of station at location in the \( i \)-th row \( j \)-th column. \( x_{ij} = 0 \) denotes that the frequency \( f_{ij} \) is not allocated to the station at location in the \( i \)-th row \( j \)-th column. Otherwise, \( x_{ij} = 1 \) denotes that the frequency \( f_{ij} \) is allocated to the station at location in the \( i \)-th row \( j \)-th column.

Therefore, we formulate the objective function according to the constraints and optimization objective mentioned above as follows,

\[
\text{max } z(A) = \frac{1}{nk} \sum_{i=1}^{n} \sum_{j=1}^{k} x_{ij} - \frac{1}{nk-1} \sum_{i=1}^{n} \sum_{j=1}^{k} \sum_{s=1}^{k} x_{ij} - y_{ij} \]

\[
\begin{align*}
\sum_{i=1}^{n} x_{ij} & \leq n_t \\
\sum_{j=1}^{k} x_{ij} + x_{ij+(r+1)} & = 0 \\
\sum_{j=1}^{k} x_{ij} x_{ij+(r+1)} & = 0 \\
\sum_{j=1}^{k} x_{ij} x_{ij+(r+1)}' & = 0 \\
x_{ij} & = (x_{i-1,j} \cup x_{i-1,j+r} \cup x_{i-1,j-r} \cup x_{i-1,j+1} \cup x_{i-1,j-1} \cup x_{i-1,j+1} \cup x_{i-1,j-1} \cup x_{i-1,j+1} \cup x_{i-1,j-1}) \\
x_{ij}' & = (x_{i-1,j} \cup x_{i-1,j+r} \cup x_{i-1,j-r} \cup x_{i-1,j+1} \cup x_{i-1,j-1} \cup x_{i-1,j+1} \cup x_{i-1,j-1} \cup x_{i-1,j+1} \cup x_{i-1,j-1}) \\
y_{ij} & = \sum_{i=1}^{n} x_{ij}
\end{align*}
\]
in the $i$-th row $j$-th column. $x_{ij}^*$ denotes the union of all channels that allocated to the base stations of neighborhood’s neighborhoods of the base station in the $i$-th row $j$-th column.

It can be seen from the optimization model expression above that the optimization model consists of two parts, the first of which represents the average number of frequencies allocated by each base station. We want each base station to allocate as many frequencies as possible. The second term represents the variance of the number of frequencies allocated by all base stations in area $A$. We hope that the smaller the variance, the better, and the frequency resources allocated by each base station will be balanced as much as possible. There are four constraints, the first of which is the constraint on the number of frequencies allocated to each base station. The second term represents the co frequency and adjacent frequency interference constraints of the allocated frequencies in the same base station. The third term represents the co frequency and adjacent frequency interference constraints between the allocated frequency in any base station and the allocated frequency in adjacent base stations. The fourth term represents the co frequency and adjacent frequency interference constraints between the allocated frequency in any base station and the allocated frequency of adjacent base stations.

3.2. GA based Method for Signal Channel Allocation Optimization

In this paper, we introduce the genetic algorithm to search the solution of the proposed optimization model. There are mainly 4 part for the genetic algorithm based signal channel allocation model, coding, cross over, mutation and selection.

3.2.1. Coding. Coding is the key and difficult problem in solution for signal channel allocation representation. In this paper, we define a vector of 0s and 1s represent a frequency allocation program for one base station. Assuming that $N_0$ denotes the total number of frequency channels which are available to the telecommunications operator. Then a 0/1 vector with length of $N_0$ is used to represent the frequency allocation program for each base station as shown in Figure 2. Assume the number of base station is $N = m \times n$ in region $A$. Then, the total program is represented by a 0/1 vector of length $N_0 \times N$.

![Figure 2. Coding illustration](image)

3.2.2. Cross over. For cross over operation, the wildly used approach is used. We first select a site randomly. Then, we divided two chromosome into four gene segments. Next, we exchange the tail gene segments of the two chromosome. Finally, there are two new chromosomes generated. The approach is shown as in Figure 3.

![Figure 3. Cross over illustration](image)
3.2.3. Mutation. For mutation operation, we first select a site of the chromosome and change the value of the selected site to opposite value. The method is as follows,

\[ y = |1 - x|, x = 0 \text{ or } 1 \]

\( x \) denotes the value of the selected site of chromosome. \( y \) denotes the value of this site after mutation.

3.2.4. Selection. For selection operation, we utilize “roulette” and “elite” strategy to select the chromosomes to be preserved into the next generation in this paper. In the selection process, we need to first calculate the surviving probability of each individual. The surviving probability of each individual is defined on the fitness value. The surviving probability is defined as follows,

\[ p(x_i) = \frac{f(x_i)}{M \sum_{i=1}^{M} f(x_i)} \]

\( f(x_i) \) denotes the fitness value of the individual \( x_i \). \( M \) denotes the scale of population. In general, the optimization objective function is used to evaluate the fitness of each individual. However, there are complex constraints in this model. In this paper, the constraints are transformed into penalty items to guide the model searching for the optimal solution of the frequency allocation program. Therefore, the optimization model in model (1) could be rewritten as follows,

\[
\begin{align*}
\max & \quad z'(A) = z(A) - \alpha_1n_1 - \alpha_2n_2 - \alpha_3n_3 - \alpha_4n_4 \\
\text{s.t.} & \quad n_i \leq \sum_{j=1}^{k-1} x_{ij} \leq n_u \\
 & \quad \sum_{j=1}^{k-1} x_{ij} x_{ij+1} = 0 \\
 & \quad \sum_{j=1}^{k-1} x_{ij} x'_{ij} = 0; \sum_{j=1}^{k-1} x_{ij} x'_{ij+1} = 0 \\
 & \quad \sum_{j=1}^{k-1} x_{ij} x''_{ij} = 0; \sum_{j=1}^{k-1} x_{ij} x''_{ij+1} = 0
\end{align*}
\]

\( n_i, i=1,2,3,4 \) denotes the number of base stations that do not satisfy the \( i \)-th constraint. \( \alpha_i, i=1,2,3,4 \) denotes the balance weight for the \( i \)-th penalty items.

4. Experiments

In this paper, the model is programmed based on MATLAB and test on an example to demonstrate the effectiveness of the proposed model. In this paper, the test example is defined as: the number of available frequency channels equals to 30. \( m=5, n=5 \), then the number of base stations \( N=25 \). Set the population size of GA method equals to 1000. The iteration number equals to 1200. The balance weights \( \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 200 \), \( n_i=2 \), \( n_u=6 \). The results are shown in Figure 4, which shows the convergence curve of the optimization objective function. It is worth noting that the solution with function value greater than 0 means that the solution satisfied the constraints.
Figure 4. Convergence curve of GA based method for solution search

The optimal solution for frequency channels allocation of the given example is as following.

Table 1. Result of frequency channels allocation

| Station | Allocated frequency number | Allocated channels | Allocated frequency number | Allocated channels |
|---------|---------------------------|-------------------|---------------------------|-------------------|
| station 1 | 5 | [6,9,20,24,29] | station 14 | 2 | [12,20] |
| station 2 | 3 | [1,4,22] | station 15 | 6 | [6,8,10,14,28,30] |
| station 3 | 5 | [19,24,26,28,30] | station 16 | 3 | [15,17,23] |
| station 4 | 3 | [5,13,22] | station 17 | 3 | [11,13,21] |
| station 5 | 5 | [8,10,20,27,29] | station 18 | 3 | [8,15,23] |
| station 6 | 2 | [17,27] | station 19 | 2 | [1,4] |
| station 7 | 2 | [12,15] | station 20 | 3 | [17,24,26] |
| station 8 | 2 | [7,10] | station 21 | 5 | [3,5,7,9,26] |
| station 9 | 3 | [1,3,16] | station 22 | 4 | [1,19,28,30] |
| station 10 | 2 | [18,25] | station 23 | 3 | [6,17,26] |
| station 11 | 5 | [6,9,19,25,30] | station 24 | 4 | [11,13,21,30] |
| station 12 | 2 | [1,4] | station 25 | 5 | [7,9,15,19,28] |
| station 13 | 4 | [18,25,27,29] |

As shown in Table 1 the allocated frequency number and corresponding channels are presented. It can be easily concluded that the proposed model can efficiently find the solution that satisfied the constraints of co-channel interference and adjacent channel interference. Besides, the proposed model could make full use of frequency resources by optimal the average number of frequency channels allocated to each base station.

5. Conclusion

In this paper, we study on the frequency channels allocation problem for mobile communication base station. This problem is a typical task of optimal digital distribution strategy. It is meaningful for frequency resources assignment in mobile communication. Instead of existing method which focus on the co-channel interference and adjacent channel interference, the proposed model in this paper takes the utilization of frequency resources as the optimization objective and formulates the co-channel
interference and adjacent channel interference as constraints. Then, the constraints convert to penalty items to formulate the fitness function of GA base solutions. Moreover, we use the union of neighbor and neighbors’ neighbor to formulate the co-channel interference and adjacent channel interference instead of judging station by station. Finally, we test the proposed model on an example to demonstrate the effectiveness of the proposed model.

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