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Mixed Frequency Allocation Strategy for GSM-R

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Abstract: In this paper, the mixed frequency allocation is proposed to apply to GSM-R considering its limited capacity. The frequency points are divided into two types: fixed and dynamic. The fixed can prove the quality and the dynamic are used to increase the capacity. Also, the algorithm has been included, based on the enumeration method.

Key word: GSM-R, mixed frequency allocation, capacity, frequency point, interference.

一种应用于 GSM-R 系统的混合频率分配策略

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【摘要】鉴于 GSM-R 系统容受限，本文提出了一种混合频率分配策略。所有的频点分为固定和动态两种类型。固定频点可以保证业务质量，而动态频点可以增加系统的容量。另外，本文还提出了此策略的算法，主要基于枚举法。

【关键词】GSM-R，混合频率分配，容量，频点，干扰

1 Introduction

The GSM-R frequency band has a bandwidth of 4MHz in the 900MHz range. Its carrier frequency uplink (MS to BS) band ranges from 885 MHz to 889 MHz. The downlink (BS to MS) band ranges from 930MHz to 934MHz. This structure ensures a fully duplex system with 45MHz duplex spacing. The carrier spacing is 200kHz. Taking the 200 kHz guard bands into account it leaves a total of 19 available channels. The frequency spectrum of GSM-R system is only 4M, but has to support a lot of services, such as railway emergency call, train schedule, train control, passenger message service, etc, so it can be said that the resource of GSM-R system is seriously limited. How to get greater capacity based on the limited resource is an important thing in the study of GSM-R. As some important stations like Beijing South Station, the traffic load is much heavy. In the view of situations like this, the mixed frequency allocation strategy is proposed in this paper.

Frequency planning aims at making full use of frequency band and maximizing system capacity while controlling interfere under a certain level. It is one of key issues for cell network optimization. Frequency allocation, a NP-hard problem, has always been the difficulty in network optimization and planning. There are many researches in this field, which is focused on combinatorial optimization methods such as genetic algorithms, simulated annealing method, but these methods need certain conditions to achieve good results, not for all common situations. In addition, operation result and time are uncertain. It is difficult to achieve practical results in fixed allocation occasion, not to mention dynamic allocation occasion.

Considering the diversity and high reliability of the railway business, flexible frequency allocation strategy is necessary. For example, group handoff (an important character in railway applications) can result in sharp increase in the number of business. Although it is available to many strategies like high-priority occupation strategies, dynamic resource allocation is very important for railway communication system with resources seriously limited, which is also necessary for the business with asymmetric information like scheduling orders and passenger information services. It not only guarantees the

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acceptable QoS of high-grade services, but also makes full use of system resources.

In this paper, the mixed frequency allocation strategy is proposed. That takes full account of railway specific business of high reliability and real-time requirements. What's more, services of different grade can adopt different reuse distances. That is to say, services of high quality level can reuse a greater distance in order to protect the quality of the business. On the contrary, services of low quality level can reuse a smaller distance to make full use of system resources.

2 Principles of Frequency Planning

The most important issues for the frequency planning of a GSM-R network are given with the following two figures:

- Minimise interference (required C/I)

>>> Maximise service quality (basis for the QoS requirements)

- Maximise capacity (based on the traffic model)

>>> Within the available frequency range (19 channels)

When distributing the channels, we should follow the following principles:

1) Clear some important parameters as the carrier center frequency, channel spacing, duplex space, etc.

2) Determine the grouping method which minimizes intermodulation interference between the frequencies.

3) In the same group, the channel cannot be continuous in order to reduce the adjacent channel interference.

4) Avoid adjacent channels being allocated to adjacent cells to reduce the adjacent channel interference.

5) Consider the system capacity and development into frequency planning.

As mentioned above, most frequency planning algorithms have their own shortages. The algorithm proposed in this paper is based on the fact that the GSM-R frequency band is very narrow, only 19 channels available, which would simplify the computation. Additionally, many constraints during the progress can make the time less. The basic idea of the algorithm is enumeration method. That is to say, we will present all the combinations and select the best allocation solutions from them.

3 Algorithm for Frequency Planning

3.1 Algorithm

The algorithm in multiservice environments is as follows:

Input: n, I, fre_num, fre_num1, fre_num2, ···, fre_numn, fre_numD, reuse_dis1, reuse_dis2, ···, reuse_disn, basestation_num, group_num, cellsch[n+1][group_num].

Output: Plan [fre_num].

Step 0: Record such messages into an array: the base station number each group belongs to, the amount of base stations each group belongs to in a cluster (one cells or many), the amount of frequency points in each group. Go to step 1.

Step 1: Make num1 = 0, num2=0. Go to step 2.

Step 2: Make i = 1, and the frequency point i is allocated to the group num1. Plan [i-1] = num1. Go to step 3.

Step 3: Make the frequency point i+1 allocated to the group num2. Then compare num2 with num1. If it does not satisfy any one of three constraints as follows,

① the frequency point i+1 and the frequency point i are in the same group;

② the frequency point i+1 and the frequency point I belong to the same base station;

③ the amount of frequency points in the group num2 has meted the requirement,

Plan [i] = num2, go to step 4. Otherwise, num2 = num2+1, if num2 > group_num, go to step 6, else, go to step 3.

Step 4: i++. If i <= fre_num, num1 = num2, go to step 3. Otherwise, go to step 5.

Step 5: compute the interference inter from adjacent frequencies. If inter>I, go to step 6.Otherwise, output Plan [fre_num] and go to step 6.

Step 6: num1 = num1 + 1. If num1 > group_num, end. Othwise , go to step 2.

It is illustrated in the flow chart shown in Figure 1.

3.2 Algorithm Description

At first, some symbol definitions should be given. n is the amount of service types. I is the expectation of adjacent channel interference. Fre_numi is the amount of fixed frequency points needed by service type i in one group, fre_numD is the amout of total dynamic points in one group and reuse_disi is the reuse distance. Basestation_amount represents the amount of base stations and group_amount is the amount of groups. Cellsch[n+1][group_num] means the cell schedule, wich we need to reference to group the frequencies.

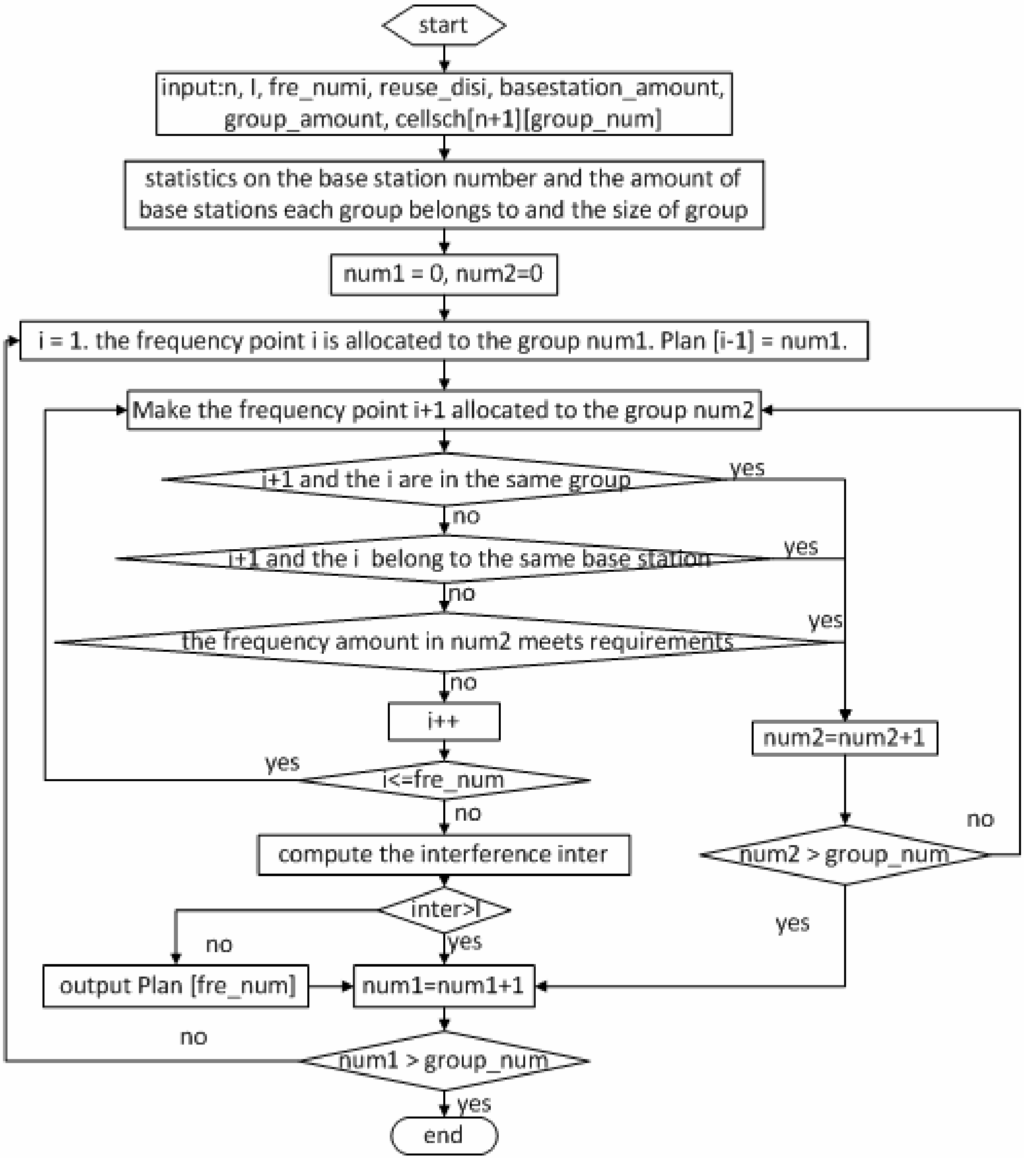

Figure 1. Flow chart of the algorithm about channel allocation

The frequency points needed by a service type include not only the fixed points but the dynamic allocated. In order to simply the progress, we can combine the dynamic allocated of the different type to a group, which is free to work for a fixed group. We can assign them according to the traffic of the types. Different types have different traffic and different quality requirements, so the reuse distances we determine are different. In the algorithm, the study unit should be the least common multiple of reuse distances of all types. We can call it a cluster, which includes at least one cell. Note that cells in railway system distribute along the chains.

The group appearing in the algorithm means the collection of frequency points which work for the same base station and have the same type of distribution (fixed or dynamic). Each point belongs to only one group and the amount, which we can also call it the group size, is decided by traffic of types that the group works for. If the amount has been achieved, there is no need to allocate any point to the group. That is reflected in the third constraint in the step 3.

In the step 1, we should calculate the base station number each group belongs to, the amount of base stations each group belongs to in a cluster and the amount of

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frequency points in each group and then record them into an array. Therefore, it has group_num rows, but the columns are more complex because of the different messages. The last column marks the group size and the penultimate column marks the amount of base stations each group belongs to in a cluster. The others correspond to the base station number each group belongs to.

From the algorithm, we can see that the only constraint to decide the allocation is suitable or not is adjacent channel interference.

The following example illustrates the points presented above.

3.3 Special Case for Two Service Types

To illustrate how to work, an algorithm with two services is presented. Let us assume that there are two types, type 1 and type 2, each of which needs one fixed point, and the total dynamic points are 4 according to the traffic and QoS. Type 1 requires higher quality so the reuse distance is determined to 6 cells, while type 2's is lower and the reuse distance is 4 cells. So, we study 12 cells as the smallest unit, called a cluster. Objectively, the cell schedule can be written as:

1	2	3	4	5	6	1	2	3	4	5	6
7	8	9	10	7	8	9	10	7	8	9	10
11	12	11	12	11	12	11	12	11	12	11	12

The array above is marked as D. Numbers in D is the labels of groups, where 12 groups exist. The 6 groups in the first line (1-6) serve type 1 and one fixed point is included. The 4 groups in the second line (7-10) serve type 2 and one fixed point is included. In the third line, the 2 groups (11-12) are distributed dynamically and each of them includes 4 points. The cell schedule like this can be written as (6 4 2). All the points involved are 18 and one is left, which can be used to coordinate the whole network.

In response to the assumption, the specific algorithm is proposed as follows:

Step 0: Input and calculate: n = 2, I = 16, fre_num = 18, fre_num1 = 1, fre_num2 = 1, fre_numD = 4, reuse_dis1 = 6, reuse_dis2 = 4, basestation_num = 12, group_num = 12, cellsch[3][12] =

1	2	3	4	5	6	1	2	3	4	5	6
7	8	9	10	7	8	9	10	7	8	9	10.
11	12	11	12	11	12	11	12	11	12	11	12

Step 1: Record such messages into an array C: the base station number each group belongs to, the amount of base stations each group belongs to in a cluster and the group size. Go to step 2.

Step 2: Make num1 = 0, num2=0. Go to step 3.

Step 3: Make i = 1, and the frequency point i is allocated to the group num1. Plan [i-1] = num1. Go to step 4.

Step 4: Make the frequency point i+1 allocated to the group num2. Then compare num2 with num1. If it cannot satisfy any one of three constraints as follows:

① num2 = num1;

② j1 and j2 are columns of C except the last two. C[i][j1] = C[i-1][j2]. C[i][j1] and C[i-1][j2] don't equal 0;

③ the amount of frequency points in the group num2 has meted the requirement;

Plan [i] = num2, go to step 6. Otherwise, num2 = num2+1, go to step 5.

Step 5: if num2 > group_num, go to step 6, else, go to step 3.

Step 6: i++. If i <= fre_num , num1 = num2, go to step 4. Otherwise, go to step 7.

Step 7: calculate the interference inter from adjacent frequencies. If inter>I, go to step 8.Otherwise, output Plan [fre_num] and go to step 8.

Step 8: num1 = num1 + 1. If num1 > group_num, end. Othwise , go to step 3.

The body of the algorithm is 18 iterative loops. It is the array C that decides whether the loop is end or not. So the array is very important. In this alglrithm, C=

1	7	0	0	0	0	2	1
2	8	0	0	0	0	2	1
3	9	0	0	0	0	2	1
4	10	0	0	0	0	2	1
5	11	0	0	0	0	2	1
6	12	0	0	0	0	2	1
1	5	9	0	0	0	3	1
2	6	10	0	0	0	3	1
3	7	11	0	0	0	3	1
4	8	12	0	0	0	3	1
1	3	5	7	9	11	6	4
2	4	6	8	10	12	6	4

, which is from step 1. Each row represents a group. The columns (1-6) show base stations the group belongs to. The column 7 means the amount of base stations while the column 8 means the amount of points in the group.

Let us take the row 8 for example. The numbers 2, 6 and 10 indicate that the group 8 works for the base stations 2, 6 and 10. The total base station amount is 3 and there is one frequency points in group 8.

4 Data Analysis

Based on the special case of two service types, let us analysis the result.

Figure 2 is the array C we get, which is fully consistent with the analysis above.

c =

1	7	0	0	0	0	2	1
2	8	0	0	0	0	2	1
3	9	0	0	0	0	2	1
4	10	0	0	0	0	2	1
5	11	0	0	0	0	2	1
6	12	0	0	0	0	2	1
1	5	9	0	0	0	3	1
2	6	10	0	0	0	3	1
3	7	11	0	0	0	3	1
4	8	12	0	0	0	3	1
1	3	5	7	9	11	6	4
2	4	6	8	10	12	6	4

Figure 2. Result of the array C

Through the program, we can see that there is no result if I < 16. The expectable combinations can be achieved only when I = 16. The following is one of the results.

Plan[18]=（7 9 8 10 1 3 5 2 6 11 12 11 12 11 12 11 12）.

The first number 7 means that the frequency point 1 is allocated to the group 7, so do others. Considering the relation between the groups and the base stations shown in cellsch, we can get the result as follows:

5	8	6	9	7	10	5	8	6	9	7	10
1	3	2	4	1	3	2	3	1	3	2	4
11	12	11	12	11	12	11	12	11	12	11	12
13	14	13	14	13	14	13	14	13	14	13	14
15	16	15	16	15	16	15	16	15	16	15	16
17	18	17	18	17	18	17	18	17	18	17	18

Frequency points 5, 8, 6, 9, 7 and 10 are fixed, allocated to the type 1 and 1, 3, 2 and 4 are also fixed, allocated to the type 2. Points 11, 12, 13, 14, 15, 16, 17 and 18 are dynamic, used in turn with the train mobile.

GSM-R has 19 frequency points (0-18). Among them, 18 frequency points are used and the point 0 is left in the algorithm. From the result, we can find that if the point 11 is replaced by the point 0, the interference will be reduced to a certain degree.

One feature of this cell schedule is that the fixed points are much less than the dynamic ones in a base station, what will increase the system capacity but oppositely reduce the stability and communication quality. To solve this problem, we can increase the fixed amount appropriately in the price of system capacity.

In the application, the reuse distances and the amount of the points in each group is determined by the requirements of the services. For example, to increase the capacity, we can reduce the reuse distance and to reduce the interference, we can increase the distance. They all depend on the requirements.

5 Conclusion

With the aim of frequency allocation to maximizing system capacity in railway multiservice environment for given requirements, the mixed frequency allocation strategy is proposed. Though it is suitable for the special environment, not only increasing the capacity but also satisfying different requirement of different services, we can see from the result that problems still exist like the system stability and balance. These are to be further studied.

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Biographies

Jiang Xiao-li, female, born in 1985, from Shandong Province, master candidate of Beijing Jiaotong University of wireless communication, interested in the research on railway communication.

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