Optimization of Cellular Radio Network

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Abstract: - This paper deals with the cellular radio network optimization. It is based on the realized experiment focused on an optimizing the GSM900 network. Bounded area in a rural region with smooth terrain is considered. Dual-slope, two-ray model is used for radio signal propagation modelling. The assigning of radio cannels to base stations and their emitted radio power are optimized. The main contribution of the work lies in detailed analysis of the criterion of optimization. An interesting solution was created by a study of interference analysis and reduction for wireless systems, usable network capacity and of its overload capacity. Method of genetic algorithms is used for solving this problem. Experiment was made in the MatLab environment.

Key-Words: - Interference, optimization, prediction, cellular, network capacity, frequency reuse

1 Introduction

The modelling and simulations of radio networks bring opportunity of theirs computational optimization. Making the design of radio-network faster is the great positive of this modelling. It can bring the saving money beside the saving time. The optimization of an allocation of used radio cannel and transmitted power of radio transmitters (base transient station in GMS system) is an attractive utilization of the radio channel modelling.

2 Cellular Structure and Frequency Reuse

The frequency spectrum is very valuable. The cellular structure was found as advantageous for frequency band utilization. This is system typical by a principle, that all serviced area is divided into a large number of small areas called the cells. Every cell is serviced by its own radio-communication unit called the Base Transient Station (BTS) in GSM system. Radio powers emitted by transceivers in these units are as small as possible for communication in the serviced cell. Thanks to radio power attenuation (in detail in chapter 2.3) from certain distance it is possible to use the radio channel with the same frequency for serving another cell. So, restricted number of radio channels can be used without limits. Uniting a group of cells with unique frequency was found as useful for the frequency planning. This group is called a cluster. The cluster size is designated by the letter N and is determined by the equation [1]

$$N = i^2 + ij + j^2 \qquad (1)$$

where i, j = 0, 1, 2, . . ., etc. As follows from (1), only the cluster sizes 3, 4, 7, 9, etc., are possible.

3 Interferences in Radio Networks

The frequency reuse brings problem of cochannel interference. The serviceable signal in cell is influenced by the others. The cluster size N is main factor, which determines carrier to noise ratio (C/I). Larger cluster size N cause higher C/I ratio, because the reuse distance becomes bigger. For cellular network, the mean C/I is given by [2]

$$C/I = 10\log\frac{S_d}{\sum_{i=1}^{n} I_i} \qquad (2)$$

where S_d is desired signal strength, I_i is the interference from the *i*th cochannel base station.

4 Field Strength Prediction

The field strength is usually predicted by the path loss modelling. Two main factors influence the path loss in considered smooth terrain. The first is the free space attenuation L_{FS} caused by geometric spreading [1]

$$L_{FS} = 32.5 + 20\log d + 20\log f \qquad (3)$$

where d is transmitter - receiver distance [km], and f is operating frequency [MHz]. The second factor of wave attenuation is the reflection. The two-ray model is often used [1]:

$$L = L_{FS}(d_b) + 20\log\left(\frac{d}{d_b}\right),\ d \le d_b \quad (4a)$$

$$L = L_{FS}(d_b) + 40\log\left(\frac{d}{d_b}\right),\ d > d_b \quad (4b)$$

where L is path loss [dB], d_b is breakpoint distance [km]

$$d_b = \frac{4h_R h_T}{\lambda} \quad (5)$$

where h_R, h_T are receiver and transmitter antenna heights [km], λ is the wave length [km].

5 Radio Network Capacity

Number of simultaneous calls is the main factor of the radio network capacity

$$C_{\text{net}} = \sum_{i=1}^{N} n_i N_{\text{TDMA}} \quad (6)$$

where N is number of assigned channels, n_i is number of repetition of ith channels and N_{TDMA} is number of calls on one channel thanks TDMA access.

As follows from (6) and [1], smaller cluster size is advantageous from the point of view of the capacity. It is caused by faster repetition of radio channels. Unluckily the decrease of cluster size increases interferences. However, there is other way how to increase the capacity. This is decreasing cells' size. But it is restricted by economic reasons.

6 Criterion of Optimization

It is very difficult to found good criterion of optimization. Maximal C/I ratio method [3]

$$Q = \frac{1}{X \cdot Y}\sum_{x=1}^{X}\sum_{y=1}^{Y}\left[\max\left(C/I_1(x,y), C/I_2(x,y),.., C/I_N(x,y)\right)\right] \quad (7)$$

where Q is the criterion, x, y determine location, X, Y determine the computational area, N is number of assigned channels; can lead to solution, which is not sufficient from the point of view of network capacity. The pure radio network capacity method (6) doesn't take the cell size and subscribers' density into account. The part of this network can't be effective exploited and the other can be overloaded on the other hand. It was found, that carrying capacity should follow the subscribers' density and therefore capacity rating Z is considered as

$$Z_{x,y} = \sum_{n=1}^{N}\sum_{j=1}^{J}\frac{N_{\text{TDMA}}}{S_{n,j}} \quad (8)$$

where $S_{n,j}$ is area [km^2], where the signal on the nth channel from jth base station is sufficient for the service. Summation of elements of Z can be used as the criterion

$$Q = \frac{1}{XY}\sum_{x=1}^{X}\sum_{y=1}^{Y} Z_{x,y} \quad (9)$$

but it still needn't lead to good spreading of Z, because double capacity rating in one element can balance zero rating in the other. The best is, when capacity rating $Z_{x,y}$ equals peak number of calls $H_{x,y}$ in every place. If $Z_{x,y} > H_{x,y}$, then network has an reserve. But if $Z_{x,y} < H_{x,y}$, then the network can be overloaded. The overloading is more important then the reserve therefore the weight function should be used. The simply way is the dual slope function

$$Zv_{x,y} = Z_{x,y},\quad \text{if } Z_{x,y} \le H_{x,y} \quad (10a)$$

$$Zv_{x,y} = H_{x,y} + n\left(Z_{x,y} - H_{x,y}\right),\ \text{if } Z_{x,y} > H_{x,y} \quad (10b)$$

where $n \in \langle 0,1 \rangle$ is an handicap of the reserve. Then the final criterion is

$$Q = \frac{1}{XY}\sum_{x=1}^{X}\sum_{y=1}^{Y} Zv_{x,y}\ . \quad (11)$$

7 Experiment

There are 17 BTS of GSM900 on the area, which locations are fixed (Fig. 1). Each of those BTS can radiates by 8 levels of emitted power (the smallest value is zero - no power, the highest value is 50W) on 3 radio channels.

At first, the two-ray model (3, 4) was used for computing the $L_{j,x,y}$ matrix of transmission coefficients between all the elements and all the BTS. Then genetic algorithm [3] was searched for the best solution of criterion (11). The rural area was considered as uniform with peak number of calls $H_{x,y}$=0.8 calls/km^2. The process was time-consuming because the criterion calculations consist of the C/I (2), of the cells' area and the capacity rating Z (8), and finally of the weight function (10). Computing was made in the Matlab environment.

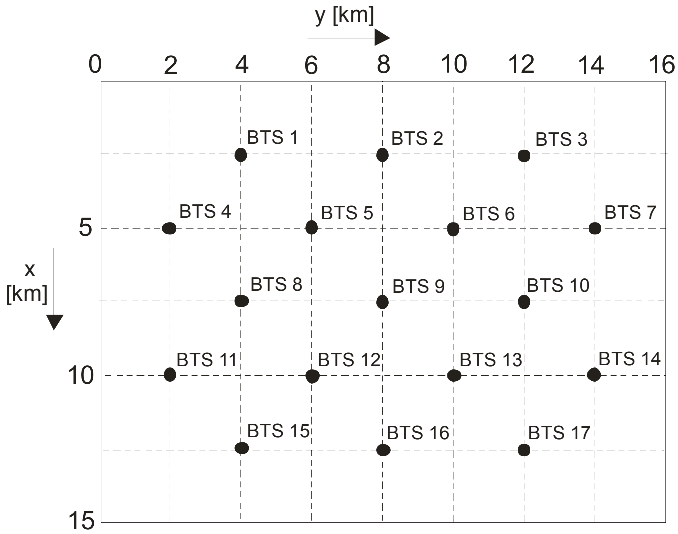

Fig.1. Computational area, location of BTS

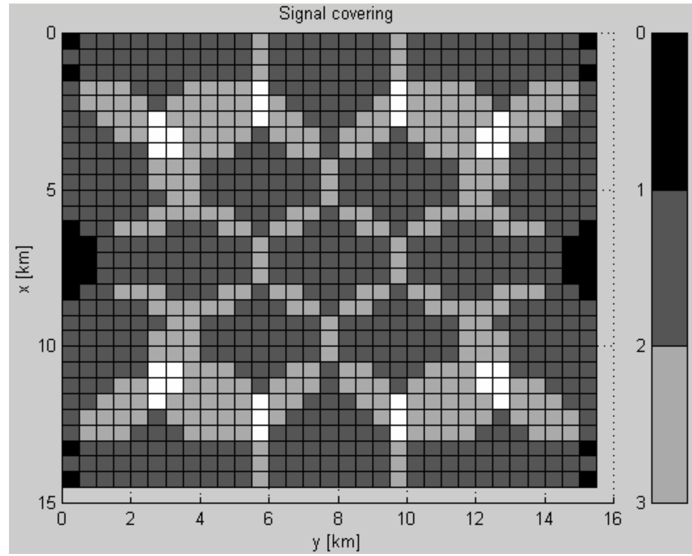

Fig.3. The best solution. Number of channels, which are available on the elements of location

8 Results

The best solution of the process (Fig. 2, 3, 4) shows that criterion leads to balanced spreading of the carrying capacity. It naturally leads to 3 cells cluster with regular frequency reuse. No covered places or places with low carrying capacity are minimized.

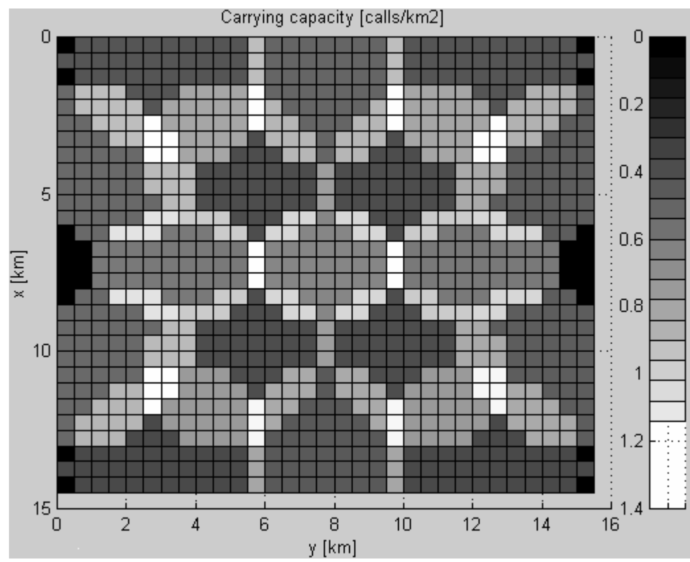

Fig.4. The best solution. Capacity rating [calls/km^2] on the elements of location

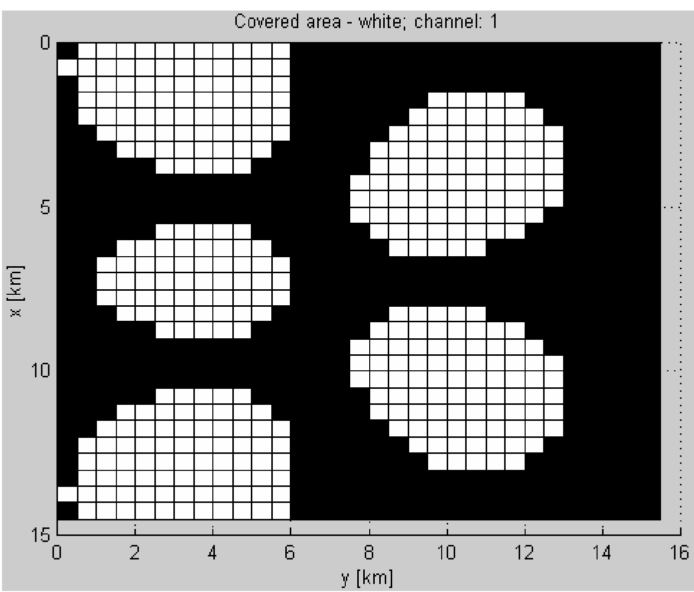

Fig.2. The best solution. Areas covered by sufficient signal on channel are white

9 Conclusions

The results of developed criterion indicate that it is possible to use it for solving real radio network optimization problems. Method can be utilized for solving more complex problems with non-uniform density of the subscribers. The complexity of computing is an disadvantage of the criterion.

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