OPTIMIZATION OF GOS OF CELLULAR NETWORK

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Abstract – The network should operate as effectively as possible with a good GoS. This is possible only with a very accurate network planning process. In this paper we consider network planning and more precisely the steps of coverage and capacity planning. We show that the optimization of these steps are possible to do simultaneously and quite in an automatic way.

I. INTRODUCTION

Traditionally the network planning is usually divided in several steps, for example to the capacity, coverage and frequency planning steps. These steps are then 'solved' separately. The targets and parameters in these steps are still not independent from each other so it would be practical if these steps could be solved simultaneously, also for economical reasons. The success of wireless network has been enormous. That is why the need of planning as effective networks as possible, has been more and more important. It is very important to the operators to serve as many customers as it is possible with a good grade of service, GoS. That is why the network planning is more and more like an optimization problem, which way it is considered in this paper. In this paper we consider a method where in the coverage planning step we take also into consideration the information of traffic density from the planning area. This information is used to plan the BS (base station) sites, their transmission powers and the number of channels in BSs in such way that the result gives a good coverage area, but also that the capacity distribution obeys traffic density in the planning area. So the targets of capacity planning are also taken into consideration and thus the step of capacity planning is almost done simultaneous with the coverage planning.

II. METHOD

There are many parameters in order to take care in network optimization. On of the most important is the GoS. The GoS consists of radio coverage, call blocking, dropping rate and transmission performance. In this paper we consider traditional network planning steps coverage and capacity planning. In coverage planning step the target is to solve BS sites, antenna types and heights and BS transmission power. In this step the demand of sufficient radio coverage, is taken care. In capacity planning the target is to take care that there is enough capacity in every point of the network planning area in order to hold especially the GoS demand of call blocking rate below the limit.

The network planning is in a real case a very complicated problem including a large amount of parameters to be solved. The search space of this kind of problem becomes easily too large to be solved as an optimizing problem. In order to make the size of the problem in a reasonable limit, the number of optimized parameters has to be reduced.

As mentioned before in the coverage planning there is four parameters to be optimized. The problem of finding optimum BS sites is a quite difficult problem even alone. If the planning area has complex geometry for example city center, it is difficult to use rough models of the coverage areas from given BS. In this case some propagation model has to be used, to get information of the obtained coverage area. The use of accurate propagation model is however quite expensive, i.e. calculating time can be significant. Also there is a problem that BSs can be sited only a very limited number of places in real case and this causes many constraints to the optimization.

In papers [3] and[2] we have considered coverage planning as an optimizing problem. We have formulated the coverage planning in the following form: Find such combination k of n possible BS sites and transmission powers that optimize the coverage area. Doing this way we suppose that there is a quite limited number of potential BS sites. From these sites, using one or several antenna solution, the achieved signal power level in the surrounding area is then calculated using some propagation model. This data is saved. This data is calculated using some transmission power level, but the influence of different transmission power can be taken into consideration easily. By formulating the coverage problem in this way, we notice that there are now only two parameters to be optimized in coverage planning: BS sites k from n possible and transmission powers.

There are two main principles to be taken care in capacity optimization: There has to be enough capacity in the network and this capacity has to be distributed to the area in the right way. Second principle is that there should be more capacity where is more subscriber and opposite. The parameters that determine networks total capacity and how it is distributed are cell layout and channels/cell. When taking previous coverage planning as a starting point, we see that the only new parameter in capacity planning is channels/cell. The cell layout is considered in coverage planning step. In this paper we focus mainly to the target that the capacity should be distributed to the planning area in the right way. Let's suppose that we have information about the traffic distribution in the planning area. This distribution measures with some unit, for example with Erlang/m^2, the amount of traffic from the measure points of the planning area. In the figure 1 is presented graphically one example of possible traffic distribution. It is quite natural that the capacity distribution should obtain this traffic distribution. This is how we compose the capacity planning: Find that combination k of n possible BS sites, transmission powers and channels/cell to them, that the obtained capacity distribution obeys traffic distribution. The first principle was to guarantee enough capacity to the planning area. This is handled also simultaneously with a suitable parameters, for example with appropriate k.

As a summary we have three parameter to be optimized: BS sites (k of n), transmission powers and channels/cell. We are dealing with discrete combinatorial optimization problem. In this paper we use Genetical Algorithm (GA [1]) in order to solve this optimization problem. They are well suitable for that problem because they need no any nice mathematical property from the problem as for example continuity or derivability. The only demand is that there is some kind of function (fitness function) that measures the 'fitness' of the solution. The better the solution is, the higher should the value of the fitness function be.

Because targets in coverage and capacity planning are different, we have to consider this problem as a multiobjective optimization. The problem is how to weight different points of fitness function so that all targets are taken care. Here we have solved this problem such that we compose two fitness function, one to the coverage planning f_1 and other f_2 to the capacity planning. Both functions are composed in such way that the values are always between 0 and 1. Final fitness function that controls optimization in GA is composed after this as follows: $\frac{a_1 f_1 + a_2 f_2}{a_1 + a_2}$, where a_1 and a_2 are the weight to the targets.

In following three numerical tests, *case1-case3*, the method considered before is used to network planning.

III. COVERAGE AND CAPACITY PLANNING; NUMERICAL EXAMPLES

The test area is following: The area is 33km*30.3km. The resolution is 50m, so measure points are 399960. There are 52 potential BS site found in this area. Problem is now to find these 20 BS site which give the optimum coverage area and that the capacity from this result obeys traffic distribution. The traffic distribution in the area is here produced in heuristic way. In the figure 1 is presented the planning area and the traffic density in this area. The darker the area is, the higher is the traffic density there.

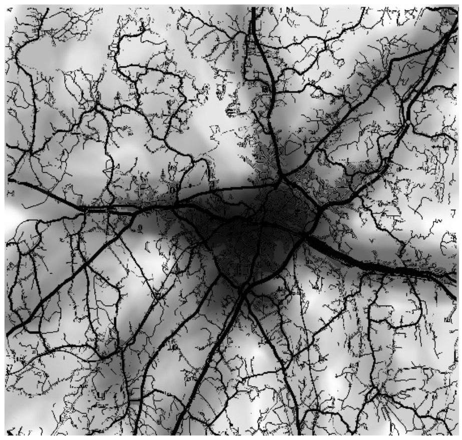

Figure 1: Planning area and traffic density

For the planning process less accuracy in the traffic data is enough. In this numerical example we consider a situation where 5 level of traffic density is used. In the figure 2 is presented the situation after this approximation. The figure is composed in a logarithmic way so that in neighbor regions the relation between the values of the traffic density is always 2.5.

The proportions of the size of the areas (region 1-5) with certain traffic density level compared with the total area size are presented in table 1.

In each region is now supposed to be the same traffic density

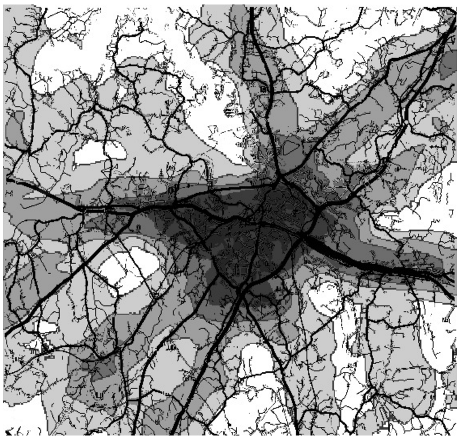

Figure 2: Planning area and rough traffic density

Table 1: Sizes of regions compared to the planning area

	Reg.1	Reg.2	Reg.3	Reg.4	Reg.5
%	24.6	38.9	23.4	7.0	6.1

level. Now we calculate the proportion of traffic from each region compared with total traffic from the planning area. The results are presented in table 2. This is the traffic distribution used in following numerical tests.

Table 2: Traffic distribution

	Reg.1	Reg.2	Reg.3	Reg.4	Reg.5
%	4.0	15.8	23.8	17.8	38.6

In the following we consider 3 cases where the problem is to find solution which optimizes the coverage area and that the network should obey traffic density considered. There are 3 parameter that affects to the result of the capacity distribution from the network. They are: Combination of BS sites, transmission powers and the number of channels in each BSs. The *cases 1-3* differ with the parameters optimized. In *case 1* we optimize parameter BS sites and transmission powers. In *case 2* parameters BS sites and number of channels/cell and in *case 3* BS sites, transmission powers and number of the channels/cell.

Case 1

In this case we try to find that combination of BS site and transmission powers to them that optimizes both the coverage area and obeys traffic density presented (two target). Because we do not here consider the number of channels in BS, we suppose that this number is the same in every BS.

We use the method presented in section II.. The constrains used in this test are following:

-n=52, k=20

-Coverage area threshold is $40 dB\mu V/m$

-Transmission power can vary between values: -6dB, -3dB, 0db or 3dB compared to the calculation level.

-Capacity density must satisfy the traffic distribution presented in figure 2 and table 2.

-$a_1 = 1$, $a_2 = 1$. Coverage and capacity targets are weighted equally.

Iteration steps were calculated 200. In the figure 3 is presented the progress of coverage area and the development of achieved capacity density in regions.

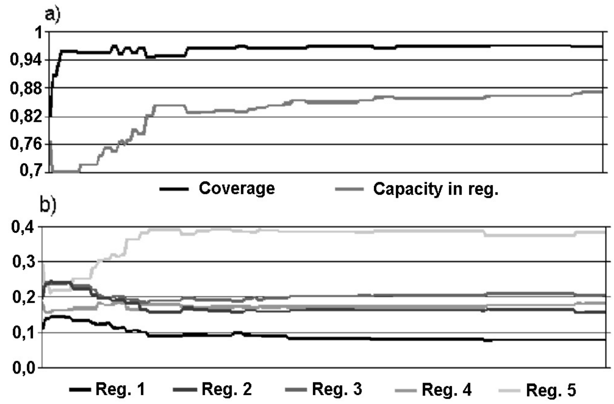

Figure 3: a) Development of coverage area and obeying traffic distribution b) Portion of capacity in regions

As we can see from the figure 3 a), the optimization works. Coverage area increases and capacity in regions obeys better traffic distribution. From the figure 3 b), we can see the distribution of capacity in regions. The exact numbers in the end of the optimization are shown in table 3. As it can be seen from this table, the values are quite near the target values presented in table 2.

Case 2

The test is the same as in *case 1*, but now we do not optimize transmission powers in addition to the BS sites. Here the optimized parameters are BS sites and the number of channels in BSs. The number of channels in BS can vary between values

1-5. The transmission power is now always 0dB compared to the calculation level. Other constrains are the same as in *case 1*.

From the figure 4 it can be seen the results of this test in the same form than in *case 1*.

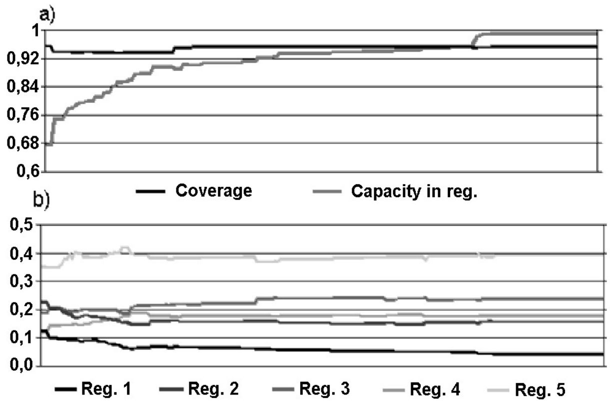

Figure 4: a) Development of coverage area and obeying traffic distribution b) Portion of capacity in regions

The results of exact portions of capacity in each region are presented in table 3.

Case 3

In the *case 3* we optimizes all three parameters: BS sites, transmission power and channels in BSs. Transmission power can vary as in the case 1 between values -6dB —3dB. Channels in BSs can vary between values 1-5, as in *case 2*.

In the figure 5 is presented the result from this numerical test.

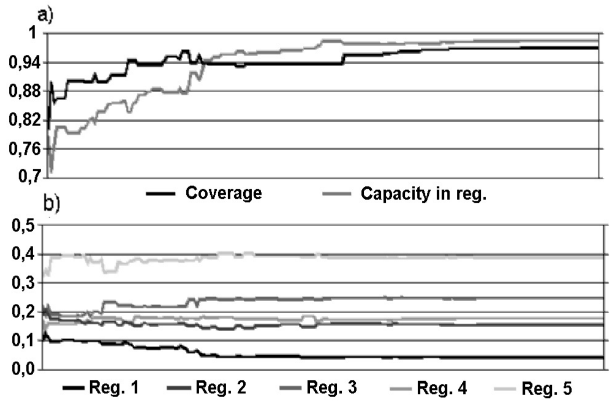

Figure 5: a) Development of coverage area and obeying traffic distribution b) Portion of capacity in regions

The capacity distribution obeys very good traffic distribution as shown in table 3

In figure 6 is presented the obtained capacity density in planning area. In gray points there are coverage and the darker the point is, more capacity to the point is available. By comparing figure 2 and 6 it can be seen that the result resembles the target.

Figure 6: Result: Capacity distribution

Analyzing cases 1-3

In table 3 is presented the result of capacity planning in *cases1-3*. From the results it can be seen that the results are quite near the object. On the other words, the optimization works. In the table 4 is presented the results of coverage planning.

Table 3: Traffic distribution and capacity distribution from the results of cases 1-3

	Reg.1	Reg.2	Reg.3	Reg.4	Reg.5
Traffic	4.0	15.8	23.8	17.8	38.6
Case1	7.8	15.8	20.1	17.8	38.5
Case2	4.0	15.5	23.6	17.7	39.2
Case3	4.0	15.3	24.6	17.5	38.6

Table 4: Achieved coverage in cases 1-3

	Case 1	Case 2	Case 3
Coverage	97.8%	96.2%	97.6%

The values of the coverage are quite high, good values. Although if we consider for example figure 3 a) we can see that in the beginning of the optimization, the level of coverage area increases but then it reminds almost in the same level. Is that so that the coverage optimization is not working after this? In figure 7 is presented the average value of the transmission power used in the best solution in each iteration step.

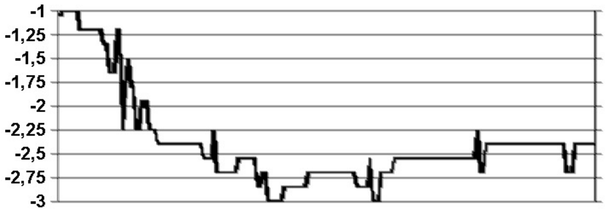

Figure 7: Average transmission power

The average power is at highest level at the beginning of optimization and after this it is decreasing. The coverage area is depending of course a lot of used transmission powers, so the coverage optimization works very well because it can still increase the achieved coverage area.

Also it can be seen from the results that the traffic distribution can be successfully taken care also when the number of channels/cell is not optimized (*case 1*). However the *case 3* gives the best solution when considering both targets. So the simultaneous BS site, transmission powers and channel/cell optimization works.

IV. CONCLUSION

This paper considers a method of performing both coverage and capacity planning simultaneously as an optimization task. In order to make this kind of optimization possible, the dimension of the optimization problem has to be reduced. Here it was done by using precalculated signal power level data from the neighborhood of BS sites. After this parameters of antenna high or type for example, has not to be taken into account. Also the number of BS sites is after this limited. In real world this is usually the case, the potential places where BS can be sited is quite limited. So using of precalculated possible BS sited, do not limit the use of this method.

In the capacity problem, the right distribution of capacity is main problem. Here we use a traffic density map, which directs the optimization in the right capacity distribution for the network under planning.

Numerical tests show that this method works and is effective.

References

[1] D. E. Goldberg. *Genetic Algorithms in Search, Optimization and Machine Learning*. Addison-Wesley Publishing Company, Inc., 1989.

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[3] Jaakko Lähteenmäki Kai Lieska, Erkki Laitinen. *Radio Coverage Optimization with Genetic Algorithms*. In proc. of Personal, Indoor and Mobile Radio communications PIMRC'98, 1998.