RADIO ACCESS OPTIMISATION FOR POINT-MULTIPOINT SYSTEMS BASED ON HOMOGENEOUS SIMULATED ANNEALING

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Abstract - We present a point-multipoint system optimisation based on simulated annealing heuristics. The system is intended to operate in the 3.5GHz frequency band mainly in densely built-in environments.

Keywords – simulated annealing, point-multipoint (pmp) systems, cooling schedule, base station (BS), radiation pattern

I. INTRODUCTION

With the assignment of the 3.5 GHz frequency band to the point-multipoint systems efficient planning algorithms are a must. There are relatively few papers dealing with wave propagation in this frequency band. Pmp system developers generally agree upon the fact that line of sight and Fresnel ellipsoid clearance, if not compulsory, do help a great deal in a successful installation.

A great number of possible BS configurations, multiple access techniques, antennas and sectorization configurations are allowed, from which we have tested only one antenna type and a sectorization type of 4 sectors/BS.

Main aspects of planning are the following: input parameters are the given number of sectors and antenna types, given maximum BS transmission powers and usable frequency sets. BS locations are supposed to be previously leased by the operator based on previous visibility analysis, as propagation above 3.5GHz is mainly of line-of-sight type and clearance of the first Fresnel ellipsoid is often a recommendation of the suppliers as well. Simulations have been performed. The optimised outputs have been the frequency sets and frequency polarizations used by the BS-s and the orientations of the antenna sectors as well. Different cooling schedules have been tested in order to find an optimum from the viewpoint of the optimisation cycles.

II. SIMULATED ANNEALING METHOD

The method of simulated annealing [1] is a technique that has attracted significant attention as suitable for optimisation problems of large scale, especially ones in that a desired global extreme is hidden among many, poorer, local extremes. At the heart of the method of simulated annealing stays an analogy with thermodynamics, specifically with the way in which liquids freeze and crystallize, or metals cool and anneal. For slowly cooled systems, nature is able to find this minimum energy state. On the other hand, if a liquid metal is cooled quickly, it does not reach this state.

So the essence of the process is slow cooling, allowing enough time for redistribution of the atoms as they lose mobility. Even at low temperatures, there is a chance of a system being in a high-energy state. Therefore, there is a corresponding chance for the system to get out of a local energy minimum in favour of finding a better, more global one. In other words, the system sometimes goes uphill as well as downhill; but the lower the temperature, the less likely gets any significant uphill excursion. From a mathematical viewpoint three functionals define completely the operation of simulated annealing, these are the PDF describing the neighbour choice – the so called neighbourhood structure, the PDF describing the acceptance of the selected neighbour – the acceptance criterion, and the cooling schedule, which describes the manner in which the control parameter is changed. There exist two different ways of implementation: the homogenous and the inhomogeneous annealing. They differ in the following: the inhomogeneous annealing applies the cooling after each neighbour selection/acceptance, and the homogenous one applies the cooling only after a number of neighbour selection/acceptance operations are accomplished. This number is a function of the equilibrium condition, which has to be carefully defined for every problem. The neighbourhood structure $N(s)$ determines for each solution s a set of possible transitions which can be proposed by s. For local search, starting from an arbitrary solution s, in each step of iterative improvement a neighbour s' of s is proposed at random. S is only replaced by s' if cost does not rise, $C(s')\leq C(s)$. This procedure terminates a local minimum, in a configuration whose neighbours do not offer any improvement in cost. Such a local minimum may have a substantially higher cost than the global one. To avoid this trapping in poor local optima, simulated annealing occasionally allows “uphill moves” to solutions of higher cost according to the so-called Metropolis criterion, which is one of the most widely used acceptance criteria. If s and $s'\in N(s)$ are the two configurations to choose from, and $C(s')>C(s)$, then the algorithm continues with configuration of s' if

$$\exp\left(-\left(C(s`)-C(s)\right)/t\right)\geq \text{random}\left[0,1\right) \tag{1}$$

Here t is a positive control parameter, which is gradually decreased to zero during the execution of the algorithm, according to the cooling schedule. t is the analogue of the temperature in the physical annealing process. The corresponding initial temperature has to be chosen high enough in order to allow for most of the proposed transitions to pass the Metropolis criterion (1). As t decreases, ever fewer proposed transitions are accepted and finally at very small values of t, now being in a local minimum, no proposed transition is accepted at all. The algorithm may stop, if there are no expectations for further substantial improvement in cost. Thus the annealing process converges to a final configuration s_{final} that could be interpreted as a solution of the discrete optimisation problem.

III. THE PROBLEM TO BE SOLVED

We used the simulated annealing method as the optimisation algorithm in a system planner program. The program is suited to design a 3.5GHz point-multipoint network. We applied the simulated annealing method with the aim of optimising the carrier-to-interference ratio (CIR) in a given system. During this optimisation the program calculates the CIR in every terminal position, and it tries to improve the worst CIR value. The interference calculations were made by the ITU-R Rec. F. 1108-2 reference. The program uses the above-mentioned optimisation during the frequency planning and the antenna rotating. Every BS sector has its own frequency, polarisation and antenna (Figure 1a and 1b). We use four-sector BS-s, where every sector has the same standard ETSI antenna [7] (Figure 1b). The terminal station antennas are also ETSI standard ones (Figure 1a).

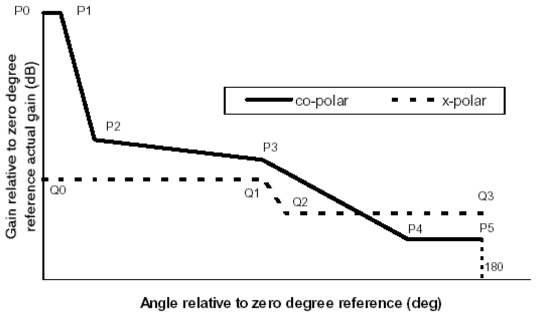

Figure 1a. Normalised Radiation Pattern Envelope for Terminal Station Azimuth and Elevation

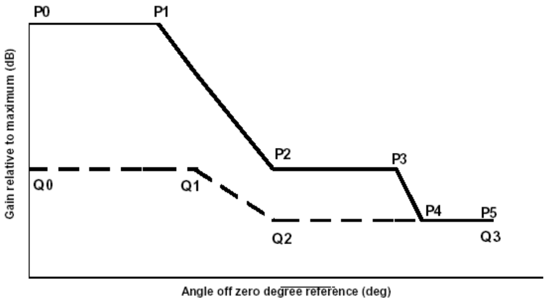

Figure 1b. Base Station sector antenna template for Azimuth and Elevation

In the starting state of the simulated annealing every BS has a frequency, a polarization. In this case, in the starting state of the simulated annealing every main lobe of the null sector of every BS is pointing to north (i.e. the null sector's direction is the 0°, while the others' in order are 90°, 180°, and 270° - see Figure 2.). Of course all sectors of a BS are rotating together.

After the initial state CIR is calculated in every terminal station position. In every optimisation cycle, the worst CIR value is chosen to increase. We search solutions in a three-dimensional solution field. This means, that the procedure creates the neighbourhood structure by the followings: first it randomly selects one BS, and then randomly chooses from the following three alternatives 1) it changes the frequency of a sector to an adjacent frequency, or 2) changes the polarization of a given frequency, or 3) rotates the antenna with plus or minus five degrees. The rotating scale is from -45° to +45°, because if we rotate more than 45° in one way, we will arrive in the neighbouring sector (see Figure 3.). This would mean another frequency allocation.

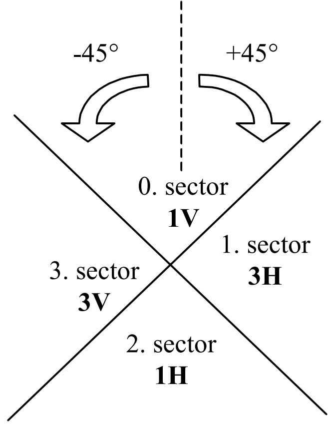

Figure 2. Rotation limit

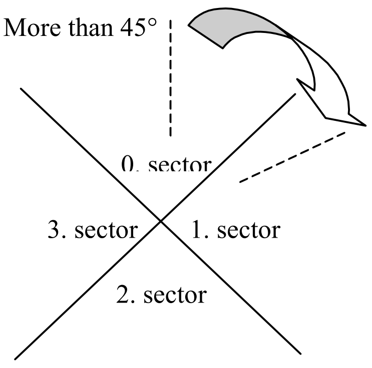

Figure 3. Example for a frequency allocation of a BS (the numbers are symbolising frequencies; H means horizontal and V means vertical polarisation)

The calculation of the control parameter T was done by the following four basic cooling schedules, as a function of the number k of optimisation steps already completed:

- Linear: $T(k)=\alpha\cdot\frac{T_0}{k}$, (2)
- Logarithmic: $T(k)=\alpha\cdot\frac{T_0}{1+\ln k}$, (3)
- Exponential: $T(k)=\alpha\cdot\frac{T_0}{e^k}$, (4)
- Constant: $T(k)=T_0\cdot\alpha^k$ (5)

where T_0 is the initial control parameter. This means that during one running period of the cooling schedule, the control parameter is decreased by a given function of α (cooling parameter). The simulation results will show how the changing of the cooling schedules affects the solution (final profit) determined by the optimisation method. On Figure 4, it is shown how fast the control parameter (T) decreases in the function of the number of optimisation steps (k).

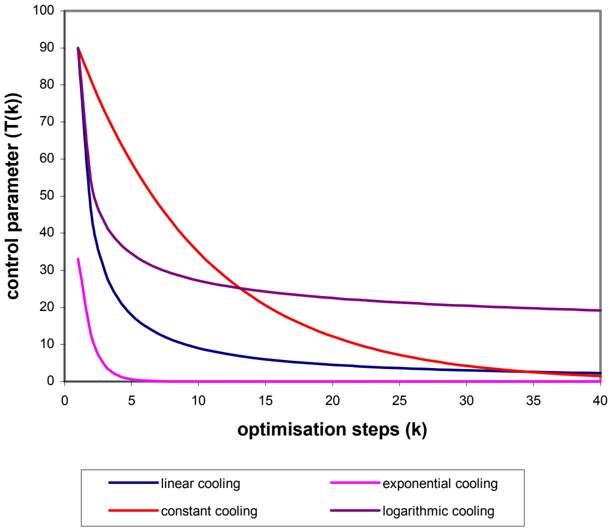

Figure 4. Cooling speed of the four basic cooling schedules

IV. SIMULATION RESULTS

The following figures show how the use of different cooling schedules affects the determination of the optimum. In our simulations the logarithmic and the linear cooling schedule turned out to be the best methods in terms of the final profit (see Figure 5.). However from the viewpoint of the optimisation speed, the exponential cooling schedule is the best choice, nevertheless with this method finding a good optimum can not be guaranteed. Logarithmic cooling schedule gives a good optimum, and with this method the algorithm is efficient and fast enough. The relations between the four schedules can be seen in the following table, from the viewpoint of the final profit and the speed (Table 1.).

Table 1. Cooling schedules relations

	Speed (# of opt. Steps)	**Final optimum**
Logarithmic c.s.	Good (250-350)	Good
Linear c.s.	Not so good (700-850)	Good
Exponential c.s.	The best (20-50)	Bad
Constant c.s.	Better (120-180)	Not so good

Choosing a cooling parameter (α) within the range of (0.8,1), will make an efficient simulated annealing method possible. Figures 6a, 6b, 6c and 6d show how the four different cooling schedules reach their final profit value.

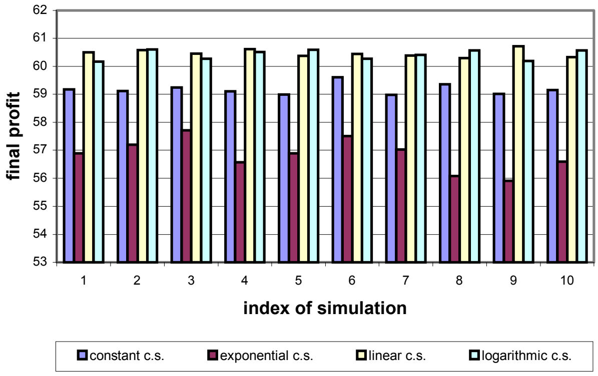

Figure 5. The final profits

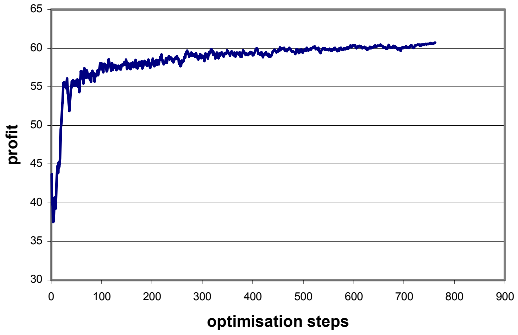

Figure 6a. Linear cooling schedule

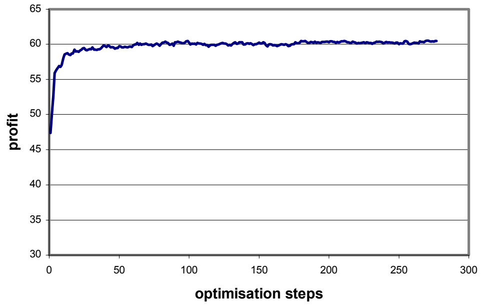

Figure 6b. Logarithmic cooling schedule

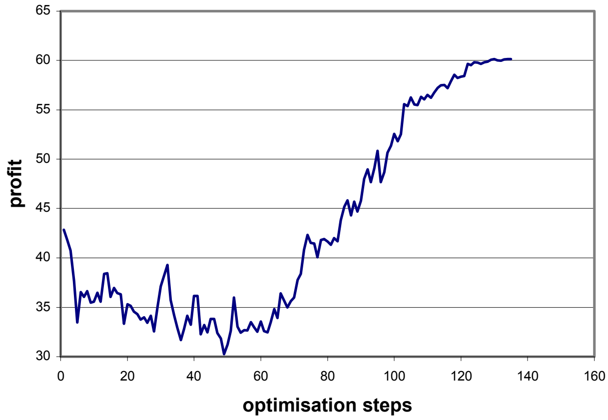

Figure 6c. Constant cooling schedule

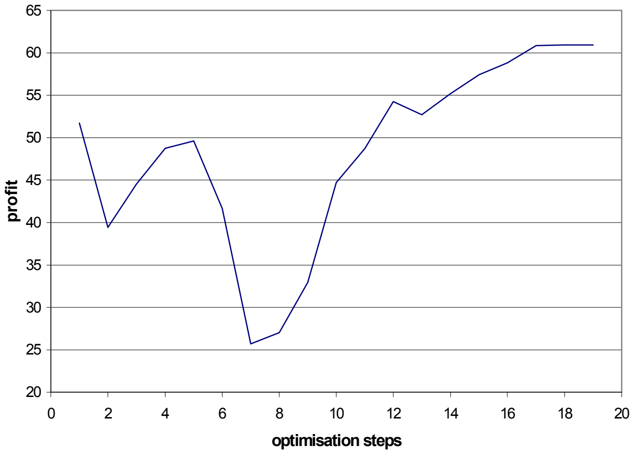

Figure 6d. Exponential cooling schedule

V. FURTHER STEPS

In the future we would like to compare the simulated annealing method to other optimisation algorithms, like Genetic Algorithms and Tabu Search. The comparison method will be like the simulation described in the "Simulation Results" section. Other alternatives are:

- comparing to other types of simulated annealing like inhomogeneous SA,
- changing system parameters like the number of BS-s or terminal stations.

In order to be able to draw more general conclusions regarding to the general applicability of simulated annealing to resolve this task, several inhomogenous annealing and also squenching algorithms as a quick, but not very reliable alternative have to be tested against each other and compared to the homogenous alternative. For the homogenous case a method for the evaluation of the appropriate chain size has to be provided that will assure a steady-state for the Markov chains at different temperatures.

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