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Study of the Simulated Annealing – Parameters in Telecommunications Network Planning Process

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Abstract: **The Algorithm of Simulated Annealing unifies the local search algorithms. In addition – Simulated Annealing allows acceptation of moves in the search space witch lead to decisions with higher cost in order to attempt to overcome any local minima obtained.**

There are four important parameters of the Simulated Annealing Algorithm witch define the normal and successful function and the obtaining of optimal decisions of the problem – Initial temperature, temperature coefficient, number of iteration on each step and stop criterion. The variation of each of them causes different results.

The goal of this work is to define the optimal values of the parameters in dependence of the problem witch must be solved.

Keywords: ***Simulated Annealing, Network planning, Concentrator location problems***

I. INTRODUCTION

Planning of telecommunications networks

The planning of telecommunications networks can be defined as follows: it must be realized the functionality of the lower 4 levels of the OSI (Open System Interconnection) reference model by fulfilling the necessary and preliminary specified technological requirements [1] [4].

These are the function which realize: the physical connectivity between the networks and between the subscribers and the network; the procedures for reliable transfer of information and signalization; the establishment, the control and the release of the connections in the network; the logical connection and the transfer of separate information blocks.

According to some works [4] there are 4 stages in the network planning process:

- building the topological structure;
- synthesis of the network;
- traffic load assignment;
- realization.

The four stages define an iterative process which has to find an optimal solution for a predefined cost function according to the geographical network plan.

The cost function may be defined in conformity with several network characteristics – realizations cost, life cycle cost, connection lengths, reliability.

Location – Allocation problems

On the first stage of the planning process the telecommunication equipment must be located and the customers must be allocated.

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The one possible way to find an optimal decision for this problem is to use cheaper communication equipment. In most cases this equipment consists of simple multiplexers - concentrators. This leads to the idea of implementing of optical technology in the concentrator networks. One possible solution is the so called PON (Passive Optical Network) [2]. The problem is – an appropriate hierarchical structure of the network to be proposed.

There are many known concentrator location problems. One of them is the UCPL (Uncapacitated Plant Location) problem, which will be used in this work.

UCPL

The mathematical model of UCPL is as follows [6]:

$$\min \sum_{i \in I} \sum_{j \in J} c_{ij} x_{ij} + \sum_{j \in J} f_j y_j \qquad (1)$$

$$\sum_{j \in J} x_{ij} = 1 \qquad (2)$$

$$x_{ij} - y_j \le 0, \qquad i \in I,\ j \in J \qquad (3)$$

$$x_{ij} \in \{0,1\}, \qquad i \in I,\ j \in J \qquad (4)$$

$$y_j \in \{0,1\}, \qquad j \in J \qquad (5)$$

where:

I is the location area;

J is set of sub areas for location of the concentrators, while $J \in I$;

C_{ij} is the cost function – it represents the cost for connecting the end node i to the concentrator j;

f_j is the cost for connecting the concentrator j to a node from the higher network level.

For the parameters x_{ij} and y_j may define:

$x_{ij} = 1$, when end node i is connected to concentrator j;

$x_{ij} = 0$, when end node i is not connected to concentrator j;

$y_j = 1$, when concentrator j is located;

$y_j = 1$, when concentrator j is not located;

The equation (1) guaranties the connectivity of one end node to one and only one concentrator. The equation (2) defines the connection of end node I to concentrator j only when the concentrator j exists.

Simulated annealing

The algorithm of the Simulated Annealing (SA) is an approach that integrates most of the local search algorithms [3]. These algorithms accept the next step only when it reduces the cost. So they reach a local minimum and stop searching.

An essential feature of simulated annealing is that it can climb out from a local minimum, since it can accept worse neighbors at the next step. Such an acceptance happens with a probability that is smaller if the neighbor quality is worse.

The probability of the acceptance can be presented as follows:

$$P\{accept\} = \begin{cases} 1, \text{ if } \Delta \le 0 \\ \exp\{-\Delta/T\}, \text{ if } \Delta > 0 \end{cases} \quad (6)$$

Δ is the cost change, and T is a control parameter that is called temperature.

The algorithm of SA has the following form:

```
Begin
  Initialize   T, Nt, Ni, s;
  for temperature step = 1 to Nt do
      for iteration = 1 to Ni do
        generate s';
        Δ = C(s') – C(s);
        if Δ ≤ 0 then
          s = s';        /*P{accept} = 1*/
          else
            s = s' with P{accept}= exp {- Δ/T};
        end if
      end for
    T = T*k;
    end for
End.
```

where:

T – temperature of the process;

Nt – number of temperature steps;

Ni – number of iterations (moves) on each temperature step;

S,s' – solutions;

C(s), C(s') – cost of solutions s and s';

K – cooling coefficient.

There are four problems by the initializing of the algorithm – defining the initial temperature, defining the cooling schedule, defining the number of iterations on each temperature step and stop criterion.

Initial temperature

The initial temperature is very important parameter and must be defined very carefully. When the initial temperature is too high the algorithm will work too long without reduce of cost, specially at the beginning of the process. The too low temperature leads to a very quick end of the process without finding the global minimum of the cost.

Often the initial temperature is being defined intuitively. In this work an optimal value of the temperature for UCPL will be searched.

Cooling procedure and cooling coefficient

In [7] there are three cooling procedures presented.

The simplest one is the geometrical cooling procedure – each next value of the temperature arise by multiplying of the old value with coefficient that is smaller than 1.

The other one is the logarithmic procedure – the new temperature depends on the decreasing speed of the temperature and on the variation of the cost by the old temperature value.

The third one is the so called exponential cooling procedure. The parameters of this procedure are the cost variation and an exponential coefficient.

II. Experimental Method and Results

In this work the initial data for the UCPL are:

- real town area;
- number of end nodes – 63;
- search space – Euclidian area – 200x200;
- three level PON with two primary nodes on fixed locations;
- initial number of concentrators – 2 to 63;
- two variants of the concentrator location – free in the search space and in the existing ducts.

The experiments are made with a computer application written by the author and called PonOpt.

Three series of test were performed in order to obtain the most appropriate values of the most important algorithms parameters. The cost is normalized with a lowest cost value because the optimum is not known.

Test 1 – Finding the optimal temperature for the process

For UCPL the optimal value is being searched between 10 000 and 1 000 000. In comparison with other similar tasks these values are low. This is because of the absence of limits for the capacity of the concentrators. The results of the test are shown on figure 1.

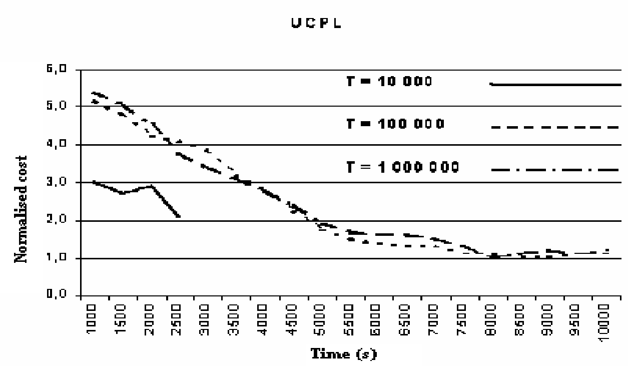

Fig. 1: The experimental results of test 1

By usage of too low temperature the process "freezes". That means – the algorithm reaches a deep local minimum and can not go any farther.

This case is presented with not dashed line on the figure.

For the next tests a value for the temperature of 500 000 is accepted, because, as shown on the figure, the optimal solution is found in very broad bounds of the initial temperature.

Test 2 – Finding the optimal cooling coefficient

The test is performed by using a geometrical cooling procedure. The values are 0.7, 0.8 and 0.9. The results are presented on the Figure 2.

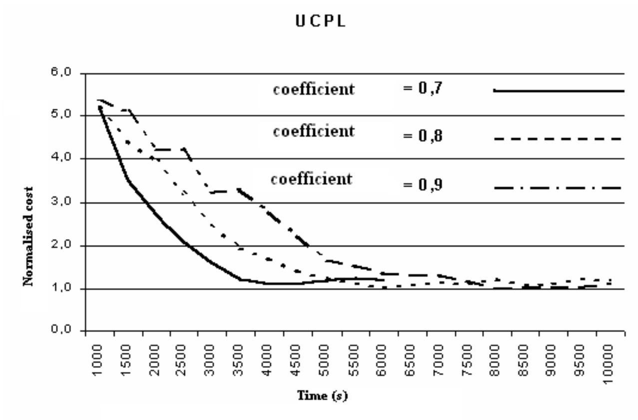

Fig. 2: The experimental results of test 2

The little coefficient value provokes a short working time without finding an optimal solution. The best results are obtained by cooling coefficient 0.9. The working time is practically the same as by coefficient 0.8. It was performed a test with coefficient 9.9 (not shown in this work). The working time is this case were 3 times longer then by 0.9 and the obtained cost was not much better.

Test 3 – Finding the optimal number of iterations (moves) on every temperature step

In order to find the optimal number value a series of tests are performed. The values that were studied are 10, 50, 200, 400 and 600 by initial temperature 500 000 and cooling coefficient – 0.9.

The most general conclusion that can be made is: the grater is the number of iterations the longer works the algorithm because of the large amount of equal solutions and the cost reduction is very slow.

The number of iterations has to be defined in dependence of the number of nodes that must be located and connected and of the search space.

The results of test 3 are shown on figure 3.

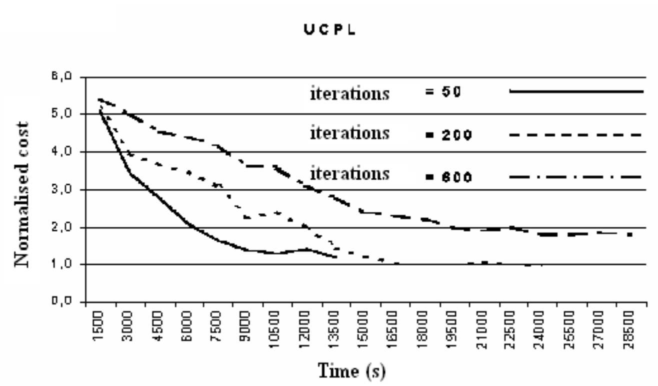

Fig. 3: The experimental results of test 3

The results of a three test are now used for solving the concrete planning problem. The initial structure of the area to be planed is shown as a text map file on the figure 4. There are primary nodes, secondary nodes (concentrators) and end nodes (customers) specified with their coordinates. The algorithm may add or remove concentrator nodes in order to find the better solution. Figure 5 shows the graphical representation on the work screen of the application PonOpt.

'Primary node description				
'P x	y			
'Secondary node description				
'S x	y			
'Customer description				
'Cx	y			
'Duct description				
'D	x1	y1	x2	y2 ..
'Primary nodes				
P 30	195			
P 110	45			
'Secondary nodes				
S 110	45			
S 30	195			
'Customers				
C 130	60			
C 150	60			
C 230	65			
C 120	70			
C 160	70			
…….………………..				
C 50	230			
'Ducts				
D 230	55	230	135	
D 220	135	220	240	
D 200	85	200	125	
D 140	60	140	95	
………………………………………………..				
D 90	130	110	90	
D 90	135	100	130	
D 100	130	200	125	

Fig. 4: The map file for planed area

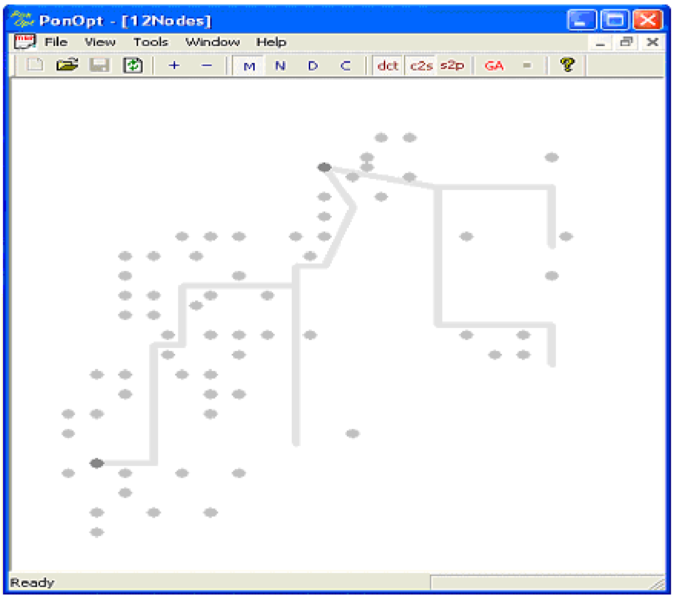

Fig. 5: The graphical presentation of the planed area with ducts

The application was started 10 times with the following parameters:

- initial temperature – 500 000;
- number of iterations – 200;

- cooling coefficient – 0.9.

In 8 of the case one and the same optimal solution was found. That proves the good definition of the initial parameters of the algorithm. The optimal solution of the planning problem is shown on figure 6.

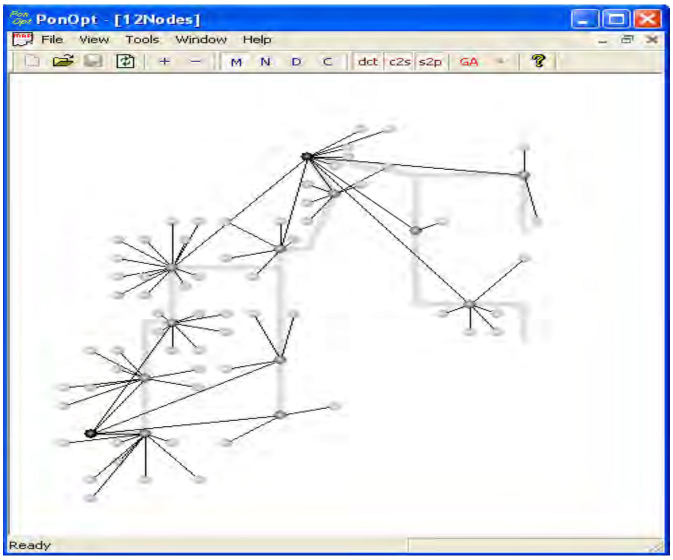

Fig. 6: The optimal solution of the planning problem

III. CONCLUSIONS

The initialization of the algorithm of Simulated annealing is very important in order to find the best solution of any optimization problem. Therefore it is necessary to spend some time to find the most appropriate values of the algorithms parameters.

The results in this work and in some other works make clear that the choice of the initial temperature of the process must give the algorithm the possibility to find the best solution in acceptable time and in conjunction with this to avoid “freezing” of the process or production of too many equal solutions.

From the results is also clear that the cooling coefficient must have a value that in not too low – the process may freeze, and at the same time not too high – the process becomes almost endless and not effective.

The optimal number of iterations on every temperature step depends on the network size and on the type of the problem. For UCPL the number of iterations is approximately equal to N*M*K (where N is the number of the primary nodes, M is the number of the secondary nodes and K is the number of the customers).

One very interesting problem may be to find an appropriate approach for dynamic (adaptive) definition of the main parameters of Simulated Annealing. That might stand for:

- finding optimal number of iterations for every single temperature step in dependence of different constraints (customer density, possible concentrator locations, concentrator capacity);
- finding optimal cooling coefficient in dependence of the results on the last temperature step.

The search for new, nontraditional methods for solving of topological problems in network planning is at the time too new for Bulgaria.

The liberalization of the telecommunications market, the existence of new network operators and their objectives (large number of services with high quality), lead to the applying of more effective approaches and algorithms for realizing of high performance networks. These approaches must be studied in near future according to their applicability in the telecommunications network planning.

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