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Solving Problems of Computer Networks' Planning Using Elastic Networks Method (Part I)

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ABSTRACT

This part of research focuses on analysis and evaluation for synthesis problem of a computer network heterogeneous structure. Where the core of the network has a ring topology, the network lower level-topology tree, and this paper composed of two interrelated parts. Firstly, this part of presented herein addresses one of problems concerned with planning of computer networks with heterogeneous structure associated with cost effectiveness. However, the second part presents other side of the computer networks' structure problem associated with optimality of network size. Specifically, at this first partfocusing attention on the cost effectiveness problem of networks' structural features using modified elastic net method. Itadopted modified method applied for reaching shortest path topology of computer network backbone structure via computing method of weight coefficient values. That solution characterized by introducing additional Synthesized weight coefficients' values taking into account the amount of internal network nodes' demands/ traffic. Interestingly, obtained solution esults after simulated experiments proved to take the advantage of better cost effectiveness(lower cost) of designed network structure , rather than other well known applicable solutions to date.

I. Introduction

The field of application of information technology and computer (ITC) is extensively represented by a growing community conceiving knowledge. That's associated with computer networks engineering due to rapid technological and social changes in addition to recent evolutionary trend associated with network engineers and scientists . Accordingly, **Solving of Computer Networks' Planning Problem** has been adopted to face increasingly challenges arose in the considered present time modifications. In this context, development of society has increased in needing to reliable and highly efficient means of information exchange. Furthermore, satisfaction of requirements for the modern computer networks is primarily achieved through the effective design. Which in turn raises the requirements for the development of effective methods for solving adopted network problem.

During proceeding for designing any computer networks' backbone, the problem of synthesis of its optimal structure (topology) arises [1],[2]. In some cases, the technology used in different areas imposes additional restrictions on the topology of the network; for example, require the organization of the network topology in the form of a ring.

Network design with the topology of the main plot in a ring in practice is difficult because it is reduced to the necessity of solving the TSP (Traveling Salesman Problem), which in turn is an NP-hard and exact solution requires exponential time [3],[4],[5],[6],[7] This article has been organized as follows. At the next section revising of computer networks' topology problem is presented in two subsections ; its mathematical formulation is presented at subsection II.(a) , however, a suggested solution of presented problem is given at subsection II.(b). The third section dedicated for introduction of the study of synthesized method of synthesis the influence of parameters on the elastic net efficiency of the method of synthesis on computer network's hierarchy to determine optimum parameters' values of computer networks. The obtained simulation results are introduced at the fourth section.Finally, conclusion is given at section 5 by the end of this work.

II. Formulation of the problem

a) Mathematical Formulation

Consider the statement and mathematical model of the synthesis of a heterogeneous network structure by a minimum value. Among the existing methods for the approximate solution of the traveling salesman problem, of particular interest is the method of elastic net [8],[9].

This approximate method refers to methods of discrete optimization in Euclidean space (when placing cities on the plane). The essence of this method is that the algorithm starts with k points ("beads") lying on an imaginary "elastic ring", where k is greater than the number of cities. The point of the ring and then move in the Euclidean space, stretching the "elastic ring," with the point of "elastic ring" are attracted to the city (Figure 1).

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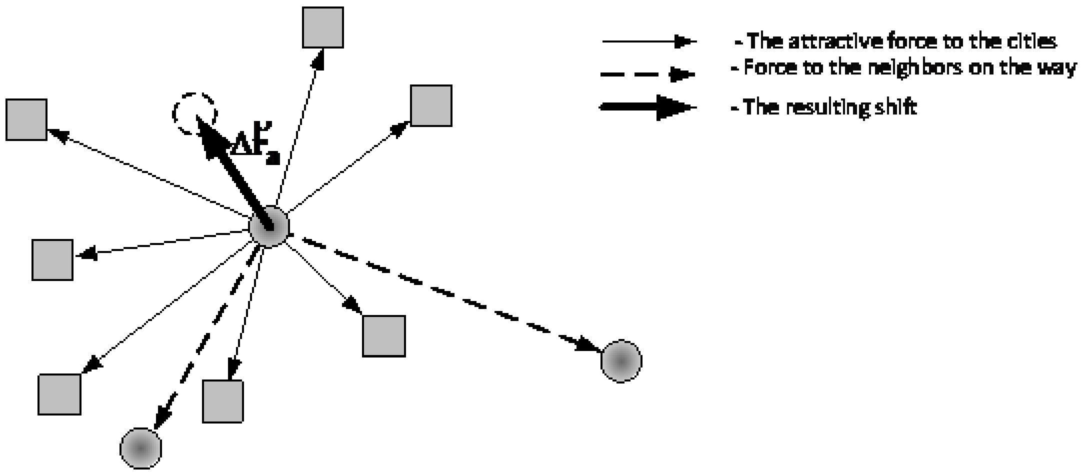

Fig. 1. The forces that act on the elastic point of the neural network

Let there be a set of subscribers $A=\{a_i\}$ - sources of information flows, and tasks. We write:

$\{x_i, y_i\}$ - geographic coordinates of location subscriber a_i;

$Z=\{z_m\}$ - possible locations of access equipment in the core segment of the network, $Z \subseteq A$;

$V=\{v_k\}$ - channels defined bandwidth, the use of which is possible with the organization of the core of the network;

$D=\|d_{ij}\|$ - matrix of costs for construction of the link between network subscribers a_i and a_j;

$D^Z=\|d_{ij}^Z\|$- matrix of reduced costs for construction of the line between points where access equipment installed on the core of the network;

$d^{LS}(u_s)$ - costs of organizing the communication channel bandwidth u_s at low speed network segment;

$d^{HS}(v_k)$ - the costs of organizing the communication channel bandwidth v_k on the core segment of the network;

$d(z_m)$ - installation costs of access equipment.

Required to determine the actual location of access equipment $Z^* \subseteq Z$ subset of users connected to each of them A_Z, $z_i \in Z^*$ so as to minimize total adjusted costs of networking in general, subject to the limitations associated with the use of access equipment and operational parameters of the link.

We introduce the following variables:

$c_{ij} \in U$ - bandwidth between subscribers a_i and a_j at low speed network segment;

$c_{ij}^Z \in V$ - bandwidth on the core part of the network;

$$b_{ij}=\begin{cases}1, & if\ AC\ a_i\ connected\ \ with\ a_j\ low\ speed\ communication\ channal\ ,\\ 0 & at\ worst\ variable;\end{cases}$$

$$b_j{}^Z=\begin{cases}1, & if\ at\ the\ place\ z_j\ installed\ \ access\ devices,\\ 0 & at\ worst\ variable;\end{cases}$$

$$b_{ij}^Z=\begin{cases}1, if\ the\ place\ z_i\ connected\ with\ the\ place\ \ z_j,\\ 0\ at\ worset\ variable\end{cases}$$

Need to find $c_{ij}, c_Z, b_{ij}, b_j^Z, b_{ij}^Z$, in which

$$W=\sum_{i=1}^{n}\sum_{j=1,j\neq i}^{n}\left[d^{LS}(c_{ij})+d_{ij}\right]\cdot b_{ij}+\sum_{i\in Z}\left[d(z_i)b_i{}^Z+\sum_{j\in Z}\left[d^{HS}(c_{ij}{}^Z)+d_{ij}{}^Z\right]\cdot b_{ij}^Z\right]\rightarrow \mathbf{min}$$

Provided that:

$$f_{ij}^{LS}\le c_{ij},\quad \forall i,j\in A, b_{ij}\neq 0; \tag{1}$$

$$f_{ij}^{HS}\le c_{ij}^Z,\quad c_{ij}^Z\in V\quad \forall i,j\in Z^*, b_{ij}^Z\neq 0; \tag{2}$$

$$c_{ij}^{Z} = c^{Z}, \quad \forall i, j \in Z^{*}, b_{ij}^{Z} \neq 0; \tag{3}$$

$$\sum_{j \in Z^{*}} b_{ij}^{Z} = 2, \quad \forall i \in Z^{*}, \quad \forall i, j \in Z^{*} \quad \exists P(i, j) \subseteq Z^{*}. \tag{4}$$

Where f_{ij}^{LS} - traffic in the link between subscribers a_i and a_j at low speed network segment;

f_{ij}^{HS} - traffic in the communication channel between the point where the equipment is installed on a high-speed access network area;

c^{Z} - bandwidth connection on the main part of the network.

Clarify the meaning of constraints. Inequality (1) and (2) take into account the restriction on traffic in the channel and the value of the capacity, which should be selected from a range of acceptable values. Condition (3) refers to the requirement that all links on the main part of the network have the same capacity. Condition (4) points to the requirement that the main plot has a ring structure, and brings all nodes where installed access equipment.

b) Solution of the problem

The solution of such a problem occurs in several stages:

- to find on the number and placement of hubs and link terminals to hubs;
- design of the access network;
- design of the core segment.

The idea of this iterative method is that if the location of hubs and link them to the terminal has already been made, the design of the access network and backbone segment is independent and can be performed separately.

In [10], for this task we propose an algorithm, built on the basis of algorithm New Clust [11] to synthesize data network hubs with a number of modifications that take into account the specifics of the problem being solved.

Analysis of the proposed algorithm has identified a number of its shortcomings:

- the high cost of computer time, which can be explained by the use of the exact algorithm for solving the traveling salesman problem on the stage of synthesis of the main topology of the segment;

- selecting nodes that will be installed access equipment is not considered their relative position. This leads to an increase in the length of the main segment, which has a higher unit cost of construction of the line of communication, and therefore increases the cost of the network.

To address these deficiencies in appear at[12],[13], the algorithm of solving the problem, which is at the stage of deciding on the number and placement of hubs, make a preliminary decision subtasks design trunk segment. It uses the technique of elastic net [8], successfully used to solve the traveling salesman problem with a set of elastic net modifications as briefly described at [8]. Thisnet simply represented analogously to a certain number of beads connected by an elastic rubber band forming a ring. The mainideafor suggested method is given in details as follows. By using an iterative procedure, the circular closed route gradually extended tonon-uniform as long as, in the end, will not pass close enough to all the cities, thus defining the route.

Denote the city and pick up for these cities according to the point ("beads") way $\vec{r}_a$ so that $\sum_a |\vec{r}_a - \vec{r}_{a+1}|$ was minimal, and that each $\vec{g}_i$ Correspond to at least one $\vec{r}_a$. Dynamic equation can be written as:

$$\Delta \vec{r}_a = -\eta' \sum_i m_i \nu_{ia} (\vec{g}_i - \vec{r}_a) + \gamma T_k (\vec{r}_{a+1} - 2\vec{r}_a + \vec{r}_{a-1}) = -T_k \frac{\delta E}{\delta \vec{r}_a} \tag{5}$$

where $\Delta \vec{r}_a$ change $\vec{r}_a$ at each stage of evolution;

m_i - weight of the site which we understand the demand of the total value of the transfer of traffic for your site;

$\eta' = \eta / m_0$;

η - constant;

$m_0 = \frac{1}{n} \sum_{i=1}^{n} m_i$ - the average weight of a node;

$\vec{r}_a$ - the relative weight of the connection $\vec{g}_i$ and γ.

In relation to the length of the path;

ν_{ia} - weight, which is characterized by the corresponding beads r_a and city g_i and has the form:

$$v_{ia} = \frac{e^{-\left|\vec{g}_i - \vec{r}_a\right|^2 / 2T_k^2}}{\sum_j e^{-\left|\vec{g}_i - \vec{r}_j\right|^2 / 2T_k^2}}, \quad (6)$$

$$T_k = d_T T_{k-1}, \quad (7)$$

where, the T_k can be interpreted as the temperature decreases in the course of evolution.

Algorithm, so the procedure is consistent conversion provisions of points in the plane of the cities. Each waypoint moves under the influence of two types of forces: one force pulls them towards the nearby cities, the second force - to their neighbors on the path to minimize the total path length.

The result of this process, each city affects every part of the way. The magnitude of this effect is determined by the dependence of the first type of force on the distance from the city to the plot and the way how this force changes during the algorithm. At the beginning of all the cities has about the same effect on every point of the path. But gradually the longer distances are less preferred, and each city gets bigger impact only on the point nearest to it.

Property pulling ring towards the concentration of cities, especially in the early stages of the algorithm can be used in the design of data networks with a ring topology on the main site and taking the nodes as cities. We propose the following algorithm:

- start up the algorithm elastic net;
- after a number of iterations of the algorithm is stopped, and the ring does not pass through all the nodes in the network, but only describes a general sort of way, and the sequence of future circumvention of access nodes;
- run the procedure for selection of access nodes and their links to the ring;
- continuing the algorithm elastic net with a reduced set of nodes (only a set of nodes selected for the installation of access to the main parts of the network in the previous step);
- run the synthesis procedure access network.

As the host, where it will be installed access equipment, we take the closest to "bead" node. As a condition by which to choose the site where the equipment available, you can take the following:

$$a_i \in Z^*, \quad if \ \left(\left|\vec{g}_i - \vec{r}_{j-1}\right| + \left|\vec{g}_i - \vec{r}_{j+1}\right|\right) = \min_{z \in Z^*}\left(\left|\vec{g}_z - \vec{r}_{j-1}\right| + \left|\vec{g}_z - \vec{r}_{j+1}\right|\right)$$

A further challenge to optimize the structure of the network is performed using the earlier algorithm [10].

III. Analysis of modified of the elastic net

The investigation of the methodology elastic net. The purpose of this study is to investigate dependence of the elastic parameters of the net from its regulatory work.Before the experiment we define a list of parameters affecting the operation technique elastic net and the synthesis method in general.Elastic net is a certain number of "beads" connected elastic rubber band so as to form a ring. The change to "bead" is defined by the expression (5) under which each bead two forces. The first force, which is determined by the first term, tends to the other nodes in the net, stretching the ring. We call it the "stretch." The second force is determined by the second term, attracts "bead" to the neighbors on the route, pulling ring. We call it the "contracts".

The description of the network and flexible method of (5), (6), (7) **on her** work affects the following parameters:

η - the weight of "stretching" force;

γ - the weight of "contracts" force;

T - "temperature" elastic net at the current step;

T_0 - The initial "temperature" elastic net;

d_T - reducing the rate of "temperature";

N_{EN} - the number of "beads" in the elastic net.

Techniques for use elastic net in practice to define the conditions of the iterative procedure stop conversion provisions of the "beads" that make up the elastic net. As a condition for stopping the method can offer flexible options to achieve their network limits. Thus stopping the proposed conditions are:

$$T \le T_{\mathbf{min}} \vee D \le D_{\mathbf{min}} \vee k \ge K_{\mathbf{max}} \vee \ d_{L_{EN}} \le d_{L_{EN}\,\mathbf{min}},$$

$$D = \max_{j}\left(\min_{i\in A}\left(\left|\vec{g}_i - \vec{r}_j\right|^2\right)\right),$$

$$d_{L_{EN}} = \frac{\left|L_{EN\,k} - L_{EN\,k-1}\right|}{L_{EN\,k-1}},$$

$$L_{EN\,k} = \sum_{a=1}^{N_{EN}-1}\left|\vec{r}_a - \vec{r}_{a+1}\right|^2 + \left|\vec{r}_{N_{EN}} - \vec{r}_1\right|^2,$$

where $T_{\mathbf{min}}$ the minimum value of the "temperature",

D - the maximum distance to the nearest of the "beads" of the network node

$D_{\mathbf{min}}$ - The minimum distance between the node network and "bead"

k - the number of iteration,

$K_{\mathbf{max}}$ - The maximum number of iterations,

$d_{L_{EN}}$ - The relative change in length of the elastic net

$L_{EN\,k}$ - The length of the elastic net in k^{th} iteration.

Consider these options in more detail, as well as conduct a test of sensitivity of the method to change the scale (sensitivity to the size of the area covered by the network).

Change the scale of the operation is called a coordinate transformation $\Sigma = \{0; \vec{x}, \vec{y}\}$ coordinate system $\Sigma' = \{0; \vec{x}', \vec{y}'\}$ which satisfies the following condition:

$$\vec{x}' = \frac{1}{b}\vec{x}, \quad \vec{y}' = \frac{1}{b}\vec{y},$$

where b - a scaling factor, then for a point $A = (x, y)_{\Sigma}$ The following transformation formula:

$$A = (x, y)_{\Sigma} = (bx, by)_{\Sigma'} \tag{8}$$

If the set of nodes through which a flexible net and the tab order does not change when you change the scale of the problem, we assume that the technique is not sensitive to changes in scale. This condition, in turn, will be implemented in the event that changes the scale of the problem will lead to a proportional change in the displacement of "beads" at each iteration, at a constant direction. This means that the condition must be satisfied:

$$\Delta\vec{r}_{ak} = b\Delta r_{ak} \quad \forall a, k, \tag{9}$$

where $\Delta\vec{r}_{ak}$ - vector of mixing "beads" on the k^{th} step after scaling;

$\Delta\vec{r}_{ak}$ - vector of mixing "beads" on the k^{th} step to zoom.

Usingequation (8) to equation (5) we get:

$$\Delta\vec{r}'_a = b\left(-\eta/_{m_0}\sum_i m_i v'_{ia}\left(\vec{g}_i - \vec{r}_a\right) + \gamma T\left(\vec{r}'_{a+1} - 2\vec{r}'_a + \vec{r}'_{a-1}\right)\right). \tag{10}$$

From (10) it is clear that in order to satisfy the condition (9) is necessary to $v'_{ia} = v_{ia}$. Using equation (8) for the expression (7) we get:

$$v'_{ia} = \frac{\left(e^{-\left|\vec{g}_i - \vec{r}_a\right|^2 / 2T^2}\right)^{b^2}}{\sum_j\left(e^{-\left|\vec{g}_i - \vec{r}_j\right|^2 / 2T^2}\right)^{b^2}}. \tag{11}$$

Referring to above equation (11), $v'_{ia} \neq v_{ia}$ and hence the condition given by (9), that means t elastic net technique is sensitive to changes of scale. Additionally, from equations (10), and (11) change of scale in the k^{th} iteration, the weight of "stretch" in order to encourage a more intimate network nodes increases compared with the same iteration before scaling.

We describe a methodology according to which the study was conducted of methods elastic net.

For this study the following inputs are considered :

- data on the placement of nodes within a given territory, which limits the size of 1000 x 1000;
- the amount of claims for transfer of nodes taken equal for all nodes $\lambda_i \cdot \overline{n}_i = const$, i=1.. n_A or had an exponential distribution.

In the study, the experiment was conducted to determine the dependence of the characteristics of the methods of the parameters affecting its performance. To do this, you run the algorithm implements an elastic net method for different values of parameters. Then analyzed the results of the algorithm on each iteration. The settings were changed in the following ranges:

- weighting factor "stretch" power η = 0.1 .. 2.0; step 0.1;
- weighting factor "contracts" force γ = 0.1 .. 2.0; step 0.1;
- the initial "temperature" T_0 = 1 .. 0.2 ; step - 0.1;
- reduction rate "temperature" d_T =0.9 .. 0.99; step 0.01.

Before the experiment for the initial set of nodes done zooming by a factor of *b* takes a number of values: *b* = 0.1; 0.05; 0.02; 0.01; 0.005; 0.002; 0.001; 0.0005; 0.0002; 0.0001 (the size of the territory covered by the network is taking a number of values: 100; 50; 20; 10; 5; 2; 1; 0.5; 0.2; 0.1).

The algorithm operate with the conditions:

$k \geq k_{\mathbf{max}} \vee d_{L_{EN}} \leq d_{L_{EN}\,\mathbf{min}}$, where $k_{\mathbf{max}}$ = 200; $d_{L_{EN}\,\mathbf{min}}$ = 0.01.

The number of "beads" in the elastic net was selected based on the number of nodes in the network: $\frac{n_{EN}}{n_A} = \frac{1}{5}; \frac{1}{3}; \frac{1}{2}; 1; 1{,}1$

network Size n_A varied from 10 to 100 nodes in steps of 10.

In the "critical points" parameter is changed in smaller steps.

The analysis of the algorithm experimentally identified range of parameter values for which the use of the technique gives good results. Stop this in more detail.

Using the technique works gives good results well when the number of "beads" in the elastic net $n_{EN} \geq 4$ With a smaller number of "beads" observed unstable work methodology, which consisted in the fact that the elastic net shrinks to a point in the center of the zone location of nodes or around one of the nodes. The same result occurs when the number of nodes in the network $n_A < 7$. As the size of the network, the number of cases in which the selection of other parameters can achieve good results, increases sharply, with the size of the network $n_A > 12$ nodes observed stable performance of the algorithm (with proper choice of the values of other parameters).

The shape of the ring depends on the elastic net (formed) from the provisions of the "beads" on the plane and on their number. When working methods elastic net, it was observed that in some cases the number of "beads", involved in the formation of the ring, decreased compared to the original amount. This is due to the fact that part of the "beads" in the process of sticking together with neighbor, especially in the later stages, that is, the position of neighboring "beads" matches: $\exists\, j, \quad \vec{r}_j = \vec{r}_{j+1}$ as shown at (fig. 2)

Most often this phenomenon occurs near the sites of the network, a host "captures", "beads" elastic net. As a result, the overall trend is broken, in which each "bead" aims to take the position that coincides with one of the network nodes:

$$\forall a\ \exists i, \left|\vec{g}_i - \vec{r}_a\right| < \varepsilon, \quad \varepsilon << 1$$

Another option violation of the above trends is the case when one or more of the "beads" are in the "stretched" position between neighbors ("bead" $\vec{r}_a$ fig. 2).Therefore, in the case where it is necessary to stretch the network passes through a given number of nodes, the experimentally identified the need to select the number "beads" with a margin of 10 .. 20%.In the latter case, the number of nodes through which the elastic net, more than the number specified by the condition, so you need to use the procedure "screening sites." The essence of this procedure is the removal of a set of nodes through which the elastic net of nodes whiles the number is not equal to the specified condition.

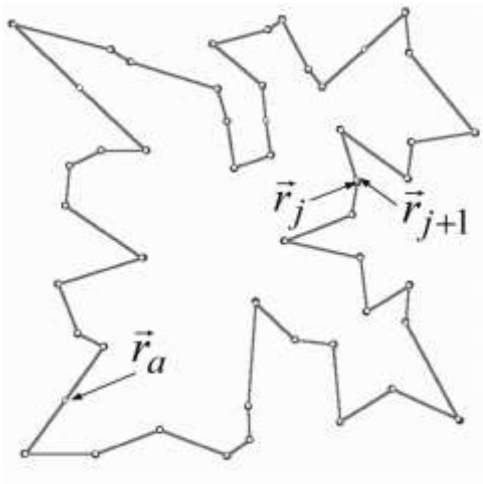

Fig. 2. The effect of reducing the number of "active beads"

IV. Simulation Results

After running of the C++ program given at the Appendix, some obtained simulation results present the most stable state that could be reached when proposed operation technique (modified elastic net method) considers territory size =10having cooling rate d_T = 0,96. Additionally, reached optimal stability observed to have three parameters η , γ ,and T_0 with values respectively. η = 0,4; γ = 1,0; T_0 = 0,3.

The two graphs at fig.3 plots resulting values the network's sizeafter the application of modified method algorithm. Noting that New Cluster (marked with squares) and the modified method of elastic net (marked with diamonds).

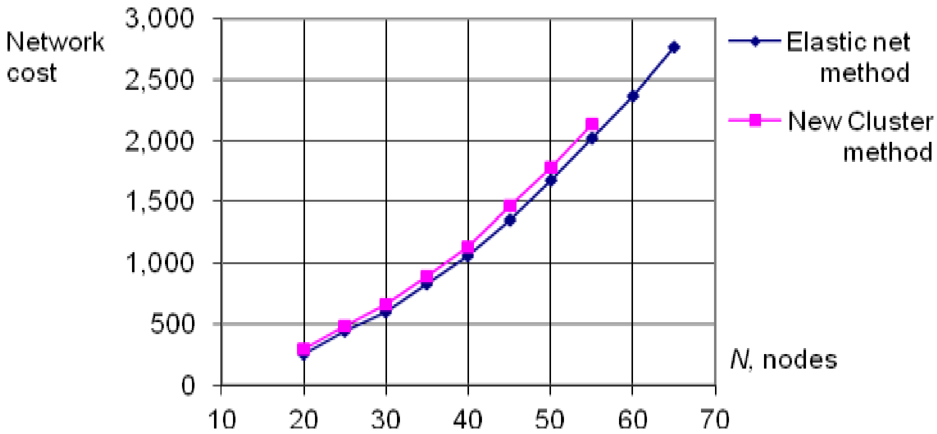

Fig. 3. Resulting network cost vs. network size

The graph shown in fig. 3 shows that as the size of the network while the method is based on a modified algorithm New Cluster sharply increases with the size of the network of more than 20 knots is much longer than the method works on the basis of elastic net. This can be explained by the need to solve during the synthesis of the main segment of the topology the traveling salesman problem; the computational complexity is proportional to the factorial of the number of nodes.Analysis of the plot of the resultant value (fig. 6) showed that the method on the basis of the average elastic net provides a lower value of the resulting value for all sizes of networks. The absolute benefit increase with the size of the network. Additionally, analysis of the plot of the resultant value (fig. 6) showed that the method on the basis of the average elastic net provides a lower value of the resulting value for all sizes of networks. The absolute benefit increase with the size of the network.

Referingtofig. 4 shows a plot of the relative gain for the value in use of the method based on elastic net, which can be determined from:

$$\Delta W = \frac{W_{NC} - W_{EN}}{W_{EN}}$$

Where WNC the resulting net cost to the method based on the algorithm New Cluster;
W_{EN} the resulting net cost to the method based on the method of ENS.

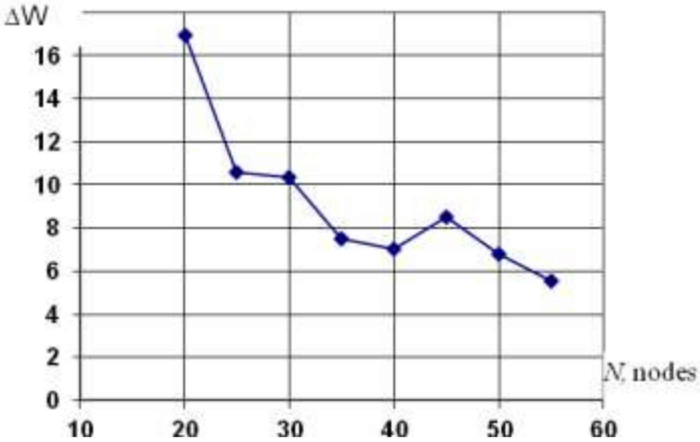

Fig. 4. Relative gain in the value of the resulting network cost vs. network size

As can be seen from Fig. 4 relative gain decreases with the size of the network from 17% to 5.5%. This can be explained by the fact that, as the network size increases the number of lines and the share in the total value contributed by "saved" the lines decreases.

V. Conclusions, and Suggestions for future work

1- The use of the proposed modification of the article elastic net with a hierarchical network design with the ring structure on the main site can synthesize the optimal topology of the main segment, which provides to the overall optimization criterion "minimum value" and takes into account the amount of traffic between nodes without resorting to the need for the exact solution of a Salesman.

2- Interestingly, it is necessary to consider rescaling step of This technique should be used in determining the topology of the main segment of a hierarchical network in the case where the cost of implementing a link between the nodes of the main segment can be taken as the distance between them. In practice, before applying the methodology proposed in the paper, you need to make a scaling of the original problem, and then you can go back to the normal view.

Finally, this work could be extended for analyis and evaluation for solving more problems associated with optimality of planning of computer network size. That will be the subject of ths second part of this work.

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