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# Tools Development of Ring Computing Network Structure Improvement

Hayk B. Avsharyan and Ruben G. Kirakossian

Yerevan State Engineering University

**Abstract:**

The current state of computer networks is discussed. The need to create the tools which will improve the structure of the network is justified. A mathematical model proposed for the improvement of the network structure. On the basis of the proposed model an algorithm which improves the structure of the ring computer network was developed.

## 1. Introduction

The current stage of the development of Global society is characterized by "Information society" transition and development [1, 2]. One of the main objectives of the "New Information Society" is its global nature. "Information Society" is gradually updated by the exchange of information and computation of the networks' aims, objectives, structures, and parameters [2, 3]. The current phase of network computing, particularly the global network/ Internet, is the most common information environment and the most immense. Due to the recent rapid growth of information that is transmitted through cellular terminals, personal computers, digital telecommunication systems, etc., the information takes longer to be transferred. The reason behind this is the transmission of large amounts of information, which in many cases affects the uninterrupted and fast work of the computing network. The problems indicated above, create serious issues for computing network operators (Providers), which are:

1. How to prevent the interruption of the network connection or how to decrease the interruptions, as much as possible, and to ensure that the customers' requirements related to the speed of information and transmission volume are met.
2. How to ensure the mentioned structural improvements stated in point 1 are rationalized in network computing in cost efficient manners and with minimum investments.

## 2. The purpose and Objectives of Research

The goal of research is to develop a ring-computing network to improve hardware and secure the defined minimum values of parameters of readiness and allowance efficiency. To achieve the nominated goal 2 consecutive problems should be solved.

Problem 1. To develop a mathematical model necessary for the computing network structure's improvement.

Problem 2. Using the developed mathematical model for the solution of problem 1, offer the improvement algorithm of ring computing network structure, ensuring the set minimum values of allowance efficiency and readiness parameters.

**The mathematical model of computer network improvement structure (Problem 1)**

Currently, there are a number of mathematical models that allow us to rationalize this or that topological computing network parameters and structure improvement [4-7]. Most of those models are implemented on the basis of mass service systems, the analytical modeling and imitation. But for the construction of these models it is necessary to know the activities of many computing networks and multi-data rates, the true value of which in many cases is impossible to find and provide [4, 5]. In addition to the majority of cases, it is recommended to improve models that do not take into account the economic costs to be carried out. As a result, these models actually are not accepted and not implemented by the economic entities. In this article, a mathematical model is developed and proposed, which does not require large amounts of basic data to be available. It improves the functioning or modernizing of the computing network structure, works by providing readiness and allowance efficiency, and yields the minimum cost; at the same time it **ensures the minimization of the financial** contribution.

For the development of mathematical model of computer network improvement we present and make the following explanations and the meanings:

• Link - receiving / sending digital cycles (DC), which are represented by $A = \{a \mid a = \overline{1,...,K}\}$ top multitude, where $K$ is the total number of the links in the observed computing net.

• The distance between the pair of links – is given by symmetric matrix:

$$H = \begin{bmatrix} 0 & h_{12} & \dots & h_{1K} \\ h_{21} & 0 & \dots & h_{2K} \\ \dots & \dots & \dots & \dots \\ h_{K1} & h_{K2} & \dots & 0 \end{bmatrix}$$

• Link load - receiving / sending DC quantity. Loading which is given according to the $|D|$ availability of the matrix:

$$D = \begin{bmatrix} 0 & d_{12} & \dots & d_{1K} \\ d_{21} & 0 & \dots & d_{2K} \\ \dots & \dots & \dots & \dots \\ d_{K1} & d_{K2} & \dots & 0 \end{bmatrix}$$

Where $d_{ij}$ is the DC quantity between the pairs of links.

• System Level - $L$, which is the maximum DC's number in synchronous transport module (STM-1 - 63 cycle, STM-4 - 252 cycle and so on).

• Network development factor - $C_{dev}$, decides the possible increase of the information transferred via computing net ($C_{dev} \geq 1$).

• The matrix of existing communication lines, cables types - $R = [R_{ij}]$, which has $K \times K$ measurability and offers the availability and the type of the fiber-optic cable.

• The existing equipment multitude - $E = [E_1,..., E_k]$.

The problem 1 of computer network improvement can be formulated as follows: the configuration of the computing network $Z = \{A, H, D, R, E\}$ and the network development the coefficient $C_{dev}$ are given. It is necessary to obtain $P = \lfloor p_{ij} \rfloor, p_{ij} = \{0,1\}$ adjusted matrix elements of the economic cost criterion minimization term basis, decreasing the holding costs of equipment and cables, ensuring the readiness and allowance efficiency values of minimal costs. The mathematical model of problem 1 will have the following form.

**Target function**

$$\min_{G^n} Q = T_m \sum_{n=1}^{N} M_n(P, L^n, E) K_m^n(G^n) T_{kind}^k(L^n) + T_L \sum_{n=1}^{K} O_n(P, H, R) T_{kind}^n(C_{dev} G^n) K_{fur}^n(O^n) \quad (1)$$

**Restrictions**

$$C_{dev} G^n \le \max L^n, \quad n = 1,\dots, N, \quad (2)$$

$$\prod_{n=1}^{N} k_{red}^n \ge 0.999 \quad (3)$$

Where (1) is a target function, costs done for computer network equipment and cables; (2) - network equipment productivity (allowance efficiency) limit; (3) - network reliability (readiness) limit;

The meanings of parameters used in (1-3) formula are as follows: $Q$ - costs to be done; $T_m$ - the average capital cost index of multiplexer unit; $G^n$ - circulated traffic by ring; $N$ - the number of network segment; $P$ - the matrix of network nodes adjustments; $L^n$ - the n segment level; $E$ - multitude of equipment used in the network; $M_n(P, L^n, E)$ - the number of used multiplexes ; $K_m^n(G^n)$ -index, which determines the level of the system; $T_{kind}^k(L^n)$ -the index, which determines the type of the used equipment; $T_L$ - index which is the average cost of used optical meter cable unit; $O_n(P, H, R)$ – is the length of used OTM; $T_{kind}^n(C_{dev} G^n)$ - an indication, which determines the type of used cable, $K_{fur}^n(O^n)$ - index, which determines the cable diversity; $K_{red}^n$ – is a network readiness coefficient which is determined with (4).

$$k_{red}^n = 1 - k_{unready}^n \quad (4)$$

where $K_{unready}^n$ – is a network not being ready coefficient which is determined with (5).

$$k_{unready}^n = \begin{cases} 0, G^n \le L^n \\ \dfrac{G^n - L^n}{G^n}, G^n \succ L^n \end{cases} \quad (5)$$

In the problem 1, it is necessary to determine the physical computing network structure (adjustment matrix) in the case of minimal value cost. Target function (1), the first of addends represents the expenses needed for network equipment and the second addend represents the expenses needed for fiber-optic cable. For the minimization of target function it is necessary to use corresponding high-speed multiplexer indicators and build rings of minimum length.

In the developed (1-3) mathematical model the restrictions take into account the necessary quality of network activity. Thus, the target function components depend on the searchable setting, $G^n$, in non-linear manner; therefore, for the solution of problem 1 the developed mathematical model (1-3), is a non-linear mathematical programming problem (one of the changes of target function arguments leads to other arguments change, but not in such a way, as in the first). The developed mathematical model (1-3) is impossible to solve by existing non-linear optimization methods [8] because we have non-linear dependence and the appearance of dependence is not known. For this reason, a simple algorithm is suggested and developed in the article, which improves the ring-structure networks structure through the easy steps.

**Computer network improvement algorithm (problem 2)**

In this article an algorithm is developed to solve the optimization problem by finding a local extremum as opposed to a global extremum of a function: that is to implement network improvements. The algorithm has been developed for ring networks, which in the current stage of development are the most common and progressive. The developed algorithm is a combination of three interconnected sub problems. The generalized flowchart of an algorithm is presented in picture 1 below. Let us describe the generalized block-scheme of the basic algorithm (figure 1) which includes all three interrelated sub - problems.

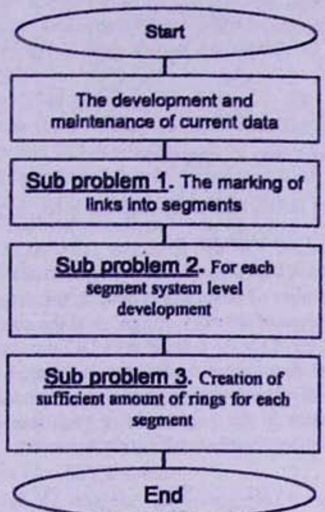


Figure 1. The developed block-scheme of the generalized basic algorithm

**Sub problem 1.** The marking of links into segments.
This sub-problem consists of the following steps:

1.1. The $C$ numbers of segments that are decided in the following way. Based on the characteristics of the equipment used in computing networks and the experience of their usage as well as based on the guidelines of the leading experts, at average, the number of the computing circles shall not exceed 16 units. Thus number of segments created from the units will be determined with $C = [K/16]$ formula, where $K$ – is the number of units.

1.2. The marking of link multitude is done as follows: $C$ numbers of units are determined based on the matrix of distances. The selection of those units is made based on the minimal summation from the current node to the remaining nodes. For each link the distance for the remaining nodes is determined:

$$H' = \sum_{j=1, j\neq i}^{K} h_{ij}, i = 1,..., K \qquad (4)$$

Then from $H'$ C amount of the minimal values are selected. The links with minimal values (4) are called central. Around the central link $C$ numbers of segments are created, through which the nodes are equally distributed into $C$ number of sectors ($360/C$) (figure 2).

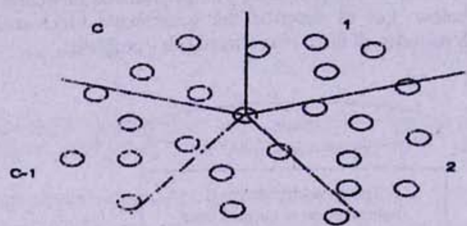


Figure 2. The distribution of links into $C$ segments

Each segment can be characterized in the following way $C^n = \{c_n, c_{n+1},..., c_{c+t_n-1}\}$, where $n$ – is for segment, $t_n$ – number of links in the segment $n$.

1.3. The establishment of segments is based on the following restrictions.

- If in the segment the number of links is less than 3, the ring turns into a line, which is not allowed under the terms of network design, or if the number of DC in the segment is less than 32 (based on STM – 1 level by DC number) the segment is being destroyed. The destroyed segment nodes are connected by the nearest neighbor segment. The selection of segment being joined is realized based on the total minimal requirements on the nodes in the segment. For each link of destroyed segment the total distance to neighboring segment units is determined:

$$H'_{prev} = \sum_{j\in C^{n-1}} h_{ij}, \; H'_{next} = \sum_{j\in C^{n+1}} h_{ij} \qquad (5)$$

  Where $n$ – the number of the destroyed segment.
  In formula (5), the least of given two dimensions determines what segment will enter the links of the destroyed segment.
- In case the number of links in the segment is more than 16, the range is divided into 2 segments. For each link of separated segment the total distance to neighboring segment units is determined:

$$H'_{next} = \sum_{j\in C^{n-1}} h_{ij} \qquad (6)$$

  where $n$ – the number of the separated segment.
  $H'_{prev}$ values are arranged in ascending order. From the arranged list $t_n/2$ values are chosen, where $t_n$ – is the number of links in the separated segment. Links that satisfy this condition form one of the new segments. The remaining links of the

dividing segment form the second new segment. The reasonableness of the link 16 uses the same logic as the proof used in the segment numbers.

1.4 The final marking of links includes the following activities:

- The pairs of successive segments are studied: The central link of segment 2 is included in the segment 1 and becomes common for segments 1 and 2.
- The same operation is carried out for 2 and 3, 3 and 4, and other segments.

After marking it is necessary to determine the level of the system, more concrete to the suitability of each segment put into STM-level.

**Sub problem 2. Decision of system level for each segment.**

The given sub problem consists of the following steps:

2.1. For each segment $TO_n$ an empty matrix $T_i \times T_i$ dimension is created, where $n$ is the segment number, $t_n$ – is the number of links in segment. The matrix is filled in the following way: all the elements of the load are considered from the biggest amount of DC. Each element participates in the observation only once. All the observed elements are marked and removed from further consideration. In addition, the following versions are possible:

- Load, that combines one segment links. In this case the matrix elements, which correspond to the links that are connected by the observed load, is added to the units transferred between DC -s number.
- Load, which connects the units of different segments that have a common link. In this case the scheme is determined by the number of possible options.
  If the segment contains one common link, then solving the problem has no vagueness, or ambiguity. Otherwise, the units that are chosen are the ones that have the least load. So, the middle load is considered as the one that is taken into account in the matrices of the 2 corresponding segments.
- Load, which connects the links with no common units and goes through several segments. If there are more than one way of communication, then from all possible routes of the successive loads is implemented the one that corresponds to the minimal standards of the intermediate loads and is equivalent to the sum of the moderate loads. After determining the combination of the common units which ensures the observed load, the elements of each segment perform the transferring of the DCs load that is added to DC's amount.

2.1. Each segment of $TO_n$ matrices is determined based on the $NP_i$ and the number of transmitted DCs, where i - is the number of the segment, ( $NP_i$ is determined by the sum of the elements that are above the main matrix's diagonal.)

2.3. If $C_{dev} > 1$, then for each segment changes are implemented in the access matrix and the number of transferred DC is increased.

2.4. On the basis of $NP_i$ the given segment STM level is clarified.

If $NP_i \leq 64$, then the segment is at STM – 1 level.

If $64 < NP_i \leq 252$, then the segment is at STM – 4 level.

If $NP_i > 252$, then the segment is at STM – 16 level.

After separating links into segments and completing the new sub matrices for each segment, the required amount of links should be created.

**Sub problem 3. Creation of required amount of rings for each segment**

It is necessary to indicate that non distributed loads (NDL) are those elements that are within the reachibility of the matrix and are not yet included in the chain.
The given sub problem consists of the following steps:
3.1. For each segment the initial quantity of chains of the following parameters are determined by: $N'' = NP_n / pred(L'')$, where $NP_n$ is the summation of DC in the segment n.
3.2 Creation of rings by calculation.
In this section, we will discuss the formation of $N'$ rings where the number of DCs is the closest to the level of $L'$ system. The rings are formed along the length of links by using "greedy" algorithm as well as by controlling non exceeding leading $pred(L'')$ loading value. In the chain of communication lines, the selection of the reassembling coverage is determined by considering the following conditions:

- $NP_n \le pred(L'')$, where $NP_n$ is the sum of the links included in the reassembling.
- The maximum value of the biggest elements of loading (in case of equal conditions) is the closest to pred($L''$) value. If none of the collections satisfy condition 1, then the number of units should be reduced by 1 in the reassembling. The action is repeated $N''$ times which is the same as the calculated amount of the rings. After each action, the links that entered the previous rings are removed from the resembled links.

3.3. Including the retained load in the created circles
The task of this part is the distribution of load in one of the circles using the methods discussed below.
3.3.1) The use of parallel ways.
This method assumes NDL distribution by channels that are created in N circles at the expense of handling the rings where there are appropriate ways. It is necessary to perform the following steps:

- Discuss the NDL in the sequence of staying out.
- Choose the rings that include appropriate ways to NDL.
- Define the NDL in other circles and other parallel ways.
- Transfer the correlations from the appropriate rings to the selected rings.

3.3.2) Including additional rings in the links
This method assumes NDL further distribution through application of additional nodes and consists of the following steps:

- Alternatively all NDLs are observed and the nodes defined that are connected with these NDLs.
- The rings were observed and it's attempted to include NDL nodes in these rings in the way that the sum of the DCs'amount of nodes will be maximum.

If after including NDL nodes DC number does not exceed the level of the system level, then the links and their ties are connected to the ring.
Ties methods including links 3.1 and 3.2 are utilized unless there are retained connections that are not included in any chain.

## 3.3 The optimization of the retrieved ring structure.

This phase aims at the optimization of the structure received from network. Optimization of network resources is carried out using criteria based on the maximum criterion. For this reason, smoothing of the rings is carried out. The problem of this block is based on the average number of rings in DC chain smoothing and it suggests realization of the following steps:

- Implement load arrangement in circles.
- Calculate the change offload in circles, where the links arrangement is carried out.

The configuration that has a maximum result of the average load network will be accepted for the final result. For the proposed conditions, the incoming data are:

1. The tables of the channel for each communication. The way is the sequence of the units and structures, through which the connection passes.
2. The amount and type of the multiplexer that are used in network links and form the necessary amount of DC.
3. Cable data. Particularly, the cable length that is used in each ring and then in entire rings.

The developed algorithm allows obtaining the ring network structure in accordance with standards formulated in Problem 1.

## Conclusion

The developed mathematical model allows, in case of very little incoming parameters, to implement:

- The network structure based on the developed algorithm in accordance with the standards formulated in the problem.
- The computer network design that is based on the algorithm which is developed and formed for more concrete rings. In addition, it allows using network resources at maximum efficiency while taking into account the possible growth of the load and providing customers with the required quality of service-information transmission.

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# Օղակաձև հաշվողական ցանցի կառուցվածքի բարելավման գործիքային միջոցների մշակում

Հ. Ավշարյան և Ռ. Կիրակոսյան

**Ամփոփում**

**Քննարկվում է հաշվողական ցանցերի ներկա վիճակը: Հիմնավորվում է հաշվողական ցանցերի կառուցվածքը բարելավող գործիքային միջոցներ ստեղծելու անհրաժեշտությունը: Առաջարկվում է օղակաձև հաշվողական ցանցի կառուցվածքի բարելավման մաթեմատիկական մոդել: Առաջարկվող մաթեմատիկական մոդելի հիման վրա մշակվել է օղակաձև հաշվողական ցանցի կառուցվածքի բարելավման ալգորիթմ:**