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Multicriteria Optimization in Telecommunication Networks Planning, Designing and Controlling

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1. Introduction

Modern telecommunication networks, irrespectively of their organization and type of the transmitted information, become more complex and possess many specific characteristics. The new generation of telecommunication networks and systems support a wide range of various communication-intensive real-time and non real-time various applications. All these net applications have their own different quality-of-service requirements in terms of throughput, reliability, and bounds on end-to-end delay, jitter, and packet-loss ratio etc. Thus, telecommunication network is a type of the information system considered as an ordered set of elements, relations and their properties. Their unique setting defines the goal searching system.

For such a type of information system as a telecommunication network it is necessary to perform a preliminary long-term planning (with structure designing and system relation defining) and a short-term operating control within networks functioning. The problem of the optimal planning, designing and controlling in the telecommunication networks involves: definition of an initial set of decisions, formation of a subset of system permissible variants, definition of an optimal criteria, and also a choice of the structure variants and network parameters, optimal by such a criteria. It is the task of a general decision making theory reduced to the implementation of some choice function of the best (optimal) system based on the set of valid variants. For the decision making tasks the following optimizing methods can be used: scalar and vector optimization, linear and nonlinear optimization, parametric and structure optimization, etc (Figueira, 2005; Taha, 1997; Saaty, 2005). We propose a method of the multicriteria optimization for optimum variants choice taking into account the set of quality indicators both in long-term and short-term planning and controlling.

The initial set of permissible variants of a telecommunication network is being formed through the definition of the different network topologies, transmission capacities of communication channels, various disciplines of service requests applied to different routing ways, etc. Obtained variants of the telecommunication network construction are estimated on a totality of given metrics describing the messages transmission quality. Thus, the formed set of the permissible design decisions is represented in the space of criteria ratings of quality indicators where, used of unconditional criteria of a preference, the subset of effective (Pareto-optimal) variants of the telecommunication network is selected. On a final stage of optimization any obtained effective variants of the network can be selected for usage. The unique variant choice of a telecommunication network with introducing some conventional criteria of preference as some scalar goal function is also possible.

In the present work some generalizations are made and all stages of solving multicriteria problems are analyzed with reference to telecommunication networks including the statement of a problem, finding the Pareto-optimal systems and selecting the only system variant. This chapter also considers the application particularities of multicriteria optimization methods at the operating control within telecommunication systems. The investigation results are provided on the example of solving of a particular management problem considering planning of cellular networks, optimal routing and choice of the speech codec, controlling network resources, etc.

2. Theoretical investigation in Pareto optimization

As far as the most general case is concerned, the system can be thought of as an ordered set of elements, relationships and their properties. The uniqueness of their assignment serves to define the system fully, notably, its structure and efficiency. The major objective of designing is to specify and define all the above-listed categories. The solution of this problem involves determining an initial set of solutions, generating a subset of pemissible solutions, assigning the criteria of the system optimality and selecting the system, which is optimal in terms of a criteria.

2.1 The problem statement in optimization system

It is assumed that the system $\varphi = (s, \vec{\beta}) \in \Phi_D$ is defined by the structure s (a set of elements and connections) and by the vector of parameters $\vec{\beta}$. A set of input actions X and output results Y should be assigned for an information system. This procedure defines the system as the mapping $\varphi : X \rightarrow Y$. The abstract determination of the system in the process of designing is considered to be exact. In particular, when formalizing the problem statement, a mathematical descripton of the working conditions (of signals, interferences) and of the functional purpose of a system (solutions obtained at the system output) are to be given, which, in fact, determine the variant of the system $\varphi \in \Phi$.

In particular, the limitations given on conditions of work, on the structure $s \in S_D$ and parameters $\beta \in B_D$, as well as on values of the system quality indicators define the subset of permissible project solutions $\Phi_a = S_a \times B_a$. Diverse ways of assigning a set of allowable are possible, in particular:

- implicit assignment using the limitations upon the operating conditions formulated in a rigorous mathematical form;
- enumeration of permissible variants of the system;
- determination of the formal mechanism for generating the system variants.

The choice of the optimal criteria is related to the formalization of the knowledge about an optimality. There exist two ways of describing the customer's preference of one variant to the other, i.e. ordinal and cardinal .

An ordinal approach is order-oriented (better-worse) and is based on introducing certain binary relations on a set of permissible alternatives. In this case the customer's preference is the binary relation R on the set Φ_D which reflects the customer's knowledge that the alternative φ' is better than the alternative: φ'': $\varphi' R \varphi''$.

Assume that a customer sticks to a certain rigorous preference $\succ$, which is asymmetric and transitive, as he decides on a set of permissible alternative Φ_D. The solution $\varphi_0 \in \Phi_D$ is called optimal with respect to $\succ$, unless there are other solution $\varphi \in \Phi_D$ for which $\varphi \succ \varphi^{(0)}$ holds true. A set of all optimal solutions in relation to $\succ$ is denoted by $\text{opt}_{\succ}\Phi_D$. A set of optimal solutions can comprise the only element, a finite or infinite number of elements as a function of the structure of a permissible set or properties of the relation $\succ$. If the discernibility relation coincides with that of equality =, then the set $\text{opt}_{\succ}\Phi_D$ (provided it is not empty) contains the only element.

A cardinal approach to describe the customer's preference assigns to each alternative $\varphi \in \Phi_D$, a certain number U being interpreted as the utility of the alternative φ. Each utility function determines a corresponding order (or a preference) R on die set $\Phi_D(\varphi' R \varphi')$ if and only if $U(\varphi') \geq U(\varphi'')$. In this case they say that the utility function $U(\cdot)$ is a preference indicator R. In point of fact this approach is related to assigning a certain scalar-objective function (a conventional preference criteria) whose optimization in a general case may result in the selection of the only optimal variant of the system.

The choice of the optimal criteria is based on formalizing the knowledge of a die system customer (i.e. a person who makes a decision) about its optimality. However, one often fails to formalize the knowledge of a decision-making person about the system optimality rigorously. Therefore, it appears impossible to assign the implicitly of the scalar optimal criteria resulting in the choice of the only decision variant $\varphi^{(0)} = \underset{\varphi \in \Phi_D}{\text{extr}}\left[U(\varphi)\right]$, where $U(\varphi)$ is a certain objective function of the system utility (or usefulness). Therefore, at the initial design stages the system is characterized by a set of objective functions:

$$\vec{k}(\varphi) = (k_1(\varphi), \ldots, k_i(\varphi), \ldots, k_m(\varphi)), \tag{1}$$

which determines the influence of the structure *s* and the parameters $\vec{\beta}$ of the variant of the system $\varphi = (s, \vec{\beta})$ upon the system quality indicators. In this connection one has to deal with the newly emerged issues of optimizing approaches in terms of a collection of quality indicators, which likewise are called the problems of multicriteria or vector optimization. Basically, the statement and the solution of a multicriteria problems is related to replacing (approximation) customer's knowledge about the system optimality with a different optimality conception which can be formalized as a certain vector optimal criteria (1) and, consequently, the problem will be solved through the effective optimization procedure.

2.2 Forming a set of permissible variants of a system

When optimizing the information systems, as their decomposition into subsystems can be assigned, it would be judicious to proceed from the morphological approach which is widely applied in designing complicated systems. In this context it is assumed that any variant of a system has a definite structure, i.e. it consists of the finite number of elements (subsystems), and the distribution of system functions amongst them can be performed by the finite number of methods.

Now consider the peculiar features of generating the structural set of permissible variants of a system. Let us assume that the functional decomposition of the system into a set of elements is

$$\{\varphi_j,\ j=\overline{1,L},\ \bigcup_{j=1}^{L}\varphi_j=\varphi\}.$$

What is considered to be assigned is as follows: a finite set of elements of the system E as well as the splitting of the set E into L morphological classes $\sigma(l), l=\overline{1,L}$ such as $\sigma(l)\cap\sigma(l')=\varnothing$ at $l\neq l'$.

A concept of the morphological space $\Lambda\subseteq 2^{\varepsilon}$ is introduced, its elements being the morphological variant of the system $\varphi=(\varphi_1,\varphi_2,\ldots,\varphi_L)$. Each morphological variant φ is a certain set of representatives of the classes $\varphi(l)\in\sigma(l)$. Here for all $\varphi\in\Lambda$ and for any $l=\overline{1,L}$ the set $\varphi\in\Lambda$ contains a single element.

Under the assumption that there exist a multitude of alternative model of implementing each subsystem $\varphi_{l\,k}$, $k=\overline{1,L}$, $l=\overline{1,L}$, the following morphological table can be specified:

Morphological classes	Possible models of implementing the system elements	Number of modes of implementing the system
$\sigma(1)$	$\varphi_{11}[\varphi_{12}]\varphi_{13}\cdots\varphi_{1K_1}$	K_1
$\sigma(2)$	$\varphi_{21}\varphi_{22}\varphi_{13}\ldots[\varphi_{2K_2}]$	K_2
………	…………………………	………
$\sigma(l)$	$\varphi_{l1}\varphi_{l2}[\varphi_{l3}]\ldots\varphi_{lK_l}$	K_l
………	…………………………	………
$\sigma(L)$	$[\varphi_{L1}]\varphi_{L2}\varphi_{L3}\cdots\varphi_{LK_L}$	K_L

Table 1. Morphological table.

As an example (see table 1), a q-th morphological variant of the system $\varphi^q=\left\langle\varphi_{12},\varphi_{2K_2},\ldots,\varphi_{l3},\ldots,\varphi_{L1}\right\rangle$ that determines the system structure is distinguished. The total number of all possible morphological variants of the system is generally determined as $Q=\prod_{l=1}^{L}K_l$.

When generating a set of permissible variants Φ_D one has to allow for the constraints upon the structure, parameters and technical realization of elements and the system as a whole as well as for the permissible combination of elements connections and constraints up on the value of the quality indicators of the system as a whole.

Here, there exist conflicting requirements. On the one hand, it is desirable to present all conceivable variants of the system in their entirety so as not to leave out the potentially best variants. On the other hand, there are limitations specified by the permissible expenditures (of time and funds) on the designing of a system.

After a set of permissible variant of a system has been determined in terms of a particular structure, the value of the quality indicators is estimated, a set of Pareto-optimal variants is distinguished and gets narrowed down to the most preferable one.

2.3 Finding the system Pareto-optimal variants

As a collection of objective functions is being introduced, each variant of the system φ is mapped from a set of permissible variants Φ_D into the criteria space of estimates $V \in R^m$:

$$V = \vec{K}(\Phi_D) = \{\vec{v} \in R^m \mid \vec{v} = \vec{k}(\varphi), \varphi \in \Phi_D\}. \tag{2}$$

In this case to each approach φ corresponds its particular estimate of the selected quality indicators $\vec{v} = \vec{k}(\varphi)$ (2) and, vice versa, to each estimate corresponds an approach (in a general way, a single approach is not obligatory).

To the relation of the rigorous preference $\succ$ on the set Φ_D corresponds the relation $\succ$ in the criteria space of estimates V. According to the Pareto axiom, for any two estimates $\vec{v}, \vec{v}'' \in V$ satisfying the vector inequality $\vec{v}' \geq \vec{v}''$, the relation $\vec{v}' \succ \vec{v}''$ is always obeyed. Besides, according to the second Pareto action for any two approaches $\varphi', \varphi'' \in \Phi_D$, for which $\vec{k}(\varphi') \geq \vec{k}(\varphi'')$ is true, the relation $\varphi' \succ \varphi''$ always occurs. The Pareto axiom imposes definite limitations upon the character of the preference in multicriteria problem.

It is desirable for a customer to obtain the best possible value for each criteria. Yet in practice this case can be rarely found. Here, it should be emphasized that the quality indicators (objective function) of the system (1) may be of 3 types: neutral, consistent with one another and competing between one other. In the first two instances the system optimization can be performed separately in terms of each of indicators. In the third instance it appears impossible to arrive at a potential value of each of the individual indicators. In this case one can only attain the consistent optimum of introduced objective functions – the optimum according to the Pareto criteria which implies that each of the indicators can be further improved solly by lowering the remaining quality indicators of the system. To the Pareto optimum in the criteria space corresponds a set of Pareto-optimal estimates that satisfy the following expression:

$$P(V) = \mathrm{opt}_{\geq} V = \{\vec{k}(\varphi^0) \in R^m \mid \forall \vec{k}(\varphi) \in V: \ \vec{k}(\varphi) \geq \vec{k}(\varphi^0)\}. \tag{3}$$

An optimum based on the Pareto criteria can be found either directly according to (3) by the exhaustive search of all permissible variants of the system Φ_D or with the use of special procedures such as the weighting method, methods of operating characteristics.

With the Pareto *weighting method* being employed. The optimal decisions are found by optimizing the weighted sum of objective functions

$$\underset{\varphi\in\Phi_D}{\text{extr}}[k_p(\varphi)=\lambda_1 k_1(\varphi)+\lambda_2 k_2(\varphi)+\ldots+\lambda_m k_m(\varphi)], \quad (4)$$

in which the weighting coefficients $\lambda_1,\lambda_2,\ldots,\lambda_m$ are selected from the condition $\lambda_i>0, \sum_{i=1}^{m}\lambda_i=1$. The Pareto-optimal decisions are the system variants that satisfy eq. (4) with different permissible combination of the weighting coefficients $\lambda_1,\lambda_2,\ldots,\lambda_m$. When solving this problem one can observe the variation in the alternative systems $\varphi=(s,\vec{\beta})\in\Phi_D$ within the limits of specified.

The method of operating characteristics consists all the objective functions, except for a single one, say, the first one, are transferred into a category of limitations of an inequality type, and its optimum is sought on a set of permissible alternatives

$$\underset{\varphi\in\Phi_D}{\text{extr}}[k_1(\varphi)],\ k_2(\varphi)=K_{2\varphi};\ k_3(\varphi)=K_{3\varphi},\ldots,\ k_m(\varphi)=K_{m\varphi}. \quad (5)$$

Here $K_{2\varphi},K_{3\varphi},\ldots,K_{m\varphi}$ are the certain fixed, but arbitrary quality indicators values.

The optimization problem (5) is solved sequentially for all permissible combinations of the values $K_{2\varphi}\le K_{2D}, K_{3\varphi}\le K_{3D},\ldots, K_{m\varphi}\le K_{mD}$. In each instance an optimal value of the indicator k_{1opt} is sought by variations $\varphi\in\Phi_D$. As a result a certain multidimensional working space in the criteria space is sought

$$k_{1opt}=f_p(K_{2\varphi},K_{3\varphi},\ldots,K_{m\varphi}). \quad (6)$$

If the found relation (6) is monotonously decreasing in nature for each of the arguments, the working surface coincides with a Pareto-optimal surface. This surface can be connected, nonconnected and just a set of isolated points.

It should be pointed out that each point of the pareto-optimal surface offers the property of a m-fold optimum, i.e. this point checks with a potentially attainable (with variation $\varphi\in\Phi_D$) value of one of the indicators k_{1opt} at the fixed (corresponding to this point) value of other ($m-1$) quality indicators. The Pareto-optimal surface can be described by any of the following relationships

$$k_{1opt}=f_{no}^{1}(k_2,k_3,\ldots,k_m),\ldots,k_{mopt}=f_{no}^{m}(k_1,k_2,\ldots,k_{m-1}), \quad (7)$$

which represent the multidimensional diagram of the exchange between the quality indicators showing the way in which the potentially attainable value of the corresponding indicator depends upon the values of other indicators.

Thus, the Pareto-optimal surface connects the potentially attainable values of index is Pareto-optimum consistent, generally dependent and competing quality indicators Therefore, with the Pareto-optimal surface in the criteria space being obtained, the multidimensional potential characteristics of the system and related multidimensional exchange diagram are found.

It should be noted that they are different types of optimization problems depending upon the problem statement.

Discrete selection. The initial set Φ_D is specified by a finite number of variants of constructing the system $\{\varphi_l, l=\overline{1,L_D}, \varphi \in \Phi_D\}$. It is required that set of Pareto-optimal variants of the system $opt_{\succ}\Phi_D$. should be selected.

Parametric optimization. The structure of the system S_D is specified. It is necessary to find the magnitude of the vectors $\vec{\beta}^0 \in B_D$ at which $\varphi = (s,\vec{\beta}) \in opt_{\succ}\Phi_D$.

Structural-parametric optimization. It is necessary to synthesize the structure $s \in S_D$ and to find the magnitude of the vector of the parameters $\vec{\beta} \in B_D$ at which $\varphi = (s,\vec{\beta}) \in opt_{\succ}\Phi_D$.

The first two types of problems have been adequately developed in the theoiy of multicriteria optimization. The solution of the third-type problems is most complicated. To synthesize the Pareto-optimal structure and find the optimal parameters a set of functionals $k_1(s,\vec{\beta}), k_2(s,\vec{\beta}),..., k_m(s,\vec{\beta})$ is to be optimized. Yet optimizing functionals even in a scalar case appears to be a rather challenging task from both the mathematical and some no less importants standpoints. In the case of a vector the solution to these types of problems becomes still more complicated. Therefore, in designing the systems with regard to a set of the quality indicators one has to simplify the optimization problem by decomposing the system into simpler subsystems, to reduce the number of quality indicators as the system structure is being synthesized.

If the set of Pareto-optimal systems variants, which has been found following the optimization procedure, turned out to be a narrow one, then any of them can be made use of as an optimal one. In this case the rigorous preference relation $\succ$ may be thought of as coinciding with the relation $\geq$ and, therefore, $opt_{\succ}V = P(V)$.

However, in practice the set $P(V)$ proves to be sufficiently wide. This implies that the relations $\succ$ and $\geq$ (although they are connected through the Pareto axiom) do not show a close agreement. Here, the inclusions $opt_{\succ}V \subset P(V)$ and $opt_{\succ}\Phi_D \subset P_{\vec{k}}(\Phi_D)$ are valid. Therefore, we will have to deal with an emerging problem of narrowing the found Pareto-optimal solutions involving additional information about the relation of the customer's rigorous preference. Yet the ultimate selection of optimal approaches should only be made within the limits of the found set of Pareto-optimal solution.

2.4 Narrowing of the set of Pareto-optimal solutions down to the only variant of a system

The formal model of the Pareto optimization problem does not contain any information to select the only alternative. In this particular instance a set of permissible variants gets narrowed only to a set of Pareto-optimal solution by eliminating the worse variants with respect to a precise variant.

However, the only variant of a system is normally to be chosen to ensure the subsequent designing stages. It is just for this reason why one feels it necessary to narrow the set of Pareto-optimal solutions down to the only variant of a system and to make use of some additional information about a customer's preference. This type of information is produced following the comprehensive analysis of Pareto-optimal variants of a system, particularly, of a structure, parameters, operating characteristics of the obtained variants of a system, a relative importance of input quality indicators, etc. Some additional information thus obtained concerning the customer's preferences is employed to construct choice function (an objective scalar function) whose optimization tends to select the sole variants of a system.

In order to solve the problem of narrowing a set of Pareto-optimal solution a diversity of approaches, especially those based on the theory of utility, the theory of fuzzy sets, etc. Now let us take a brief look at some of them.

The selection of optimal approaches using the scalar value function. One of the commonly used methods of narrowing a set of Pareto-optimal solution is constructing the scalar value function, which, if applied, gives rise to selecting one of the optimal variants of a system.

The numerical function $F(v_1, v_2, ..., v_m)$ of m variables is referred to as the value (utility) function for the relation $\succ$ if for the arbitrary estimates $\vec{v}', \vec{v}'' \in V$ the inequality $F(\vec{v}') > F(\vec{v}'')$ occurs if and only if $\vec{v}' \succ \vec{v}''$. If there exists the function of utility $F(\vec{v})$ for the relation $\succ$, then it is obvious that

$$\text{opt}_{\succ} V = \{\vec{v}^0 \in V: \; F(\vec{v}^0) = \max_{\vec{v} \in V} F(\vec{v})\}$$

and finding an optimal estimate boils down to solving the single-criteria problem of optimizing the function $F(\vec{v})$ on the set V. The value function of the type

$$F(v_1, v_2, ..., v_m) = \sum_{j=1}^{m} c_j f_j(v_j), \tag{8}$$

where c_j is the scaling factor, $f_j(v_j)$ are the certain unidimensional value function which are the estimates of usefulnen of the system variant φ in terms of the index $k_j(\varphi)$.

The construction of the value function (8) consists in estimating the scale factors, forming unidimensional utility function $f_j(v_j)$ as well as in validating their independence and consistency. Here, use is made of the data obtained from interrogating a customer. Special interrogation procedures and program packages intended to acquire some additional information about the customer's preferences have been worked out.

The selection of optimal approaches based upon the theory of fuzzy sets. This procedure is based on the fact that due to the apriori uncertainty with regard to the customer's preference, the concept such as "the best variant of a system" cannot be accurately defined. This concept may be thought of as constituting a fuzzy set and in order to make an estimate of the system, the basic postulates of the fuzzy- set theory can be employed.

Let X be a certain set of possible magnitudes of a particular quality indicator of a system. The fuzzy set G on the set X is assigned by the membership function $\xi_G : X \to [0,1]$ which brings the real number ξ_G over the interval [0,1] in line with each element of the set X. The value ξ_G defined the degree of membership of the set X elements to the fuzzy set G. The nearer is the value $\xi_G(x)$ to unity, the higher is the membership degree. The membership function $\xi_G(x)$ is the generalization of the characteristic function of sets, which takes two values only : 1 – at $x \in G$; 0 – at $x \notin G$. For discrete sets X the fuzzy set G is written as the set of pairs $G = \{x, \xi_G(x)\}$.

Thus, according to the theory of fuzzy sets each of the quality indicators can be assigned in the form of a fuzzy set

$$k_j = \{k_j, \xi_{k_j}(k_j)\},$$

where $\xi_{k_j}(\circ)$ is the membership function of the specific value of the j-th index to the optimal magnitude.

This type of writing is highly informative, since it gives an insight into its physical meaning and "worth" in relation to the optimal (extreme) value which is characterized by the membership function $\xi_{k_j}(\circ)$.

The main difficulty over the practical implementation of the considered approach consists in choosing the type of a membership function. In some sense the universal form of the membership function being interpreted in terms of the theory of fuzzy sets with regard to the collection of indicators is written as:

$$\xi_{\bar{k}}(k_1, k_2, ..., k_m) = \frac{1}{m}\left\{\sum_{l=1}^{m}[\xi_{k_j}(k_j)]^{\beta}\right\}^{\frac{1}{\beta}}. \tag{9}$$

The advantage of this form is that depending upon the parameter β a wide class of functions is implemented. These functions range from the linear additive form at $\beta = 1$ to the particularly nonlinear relationships at $\beta \to \infty$.

It should be pointed out that with this particular approach it is essential that the information obtained from a customer by an expert estimates method be used to pick out a membership function and a variety of coefficients.

Selecting optimal approaches at quality indicators strictly ordered in terms of the level of their importance. Occasionally it appears desirable for a customer to obtain die maximum magnitude of one of the indicators, say, k_1 even at the expense of the "lasses" for the remaining indicators. This means that the indicator k_1 is found to be more important than other indicators.

In addition, there may be the case where the whole set of indicators $k_1, k_2, \ldots, k_m$ is strictly ordered in terms of their importance such k_1 is more important that other indicators $k_1, k_2, \ldots, k_m$; k_2 is more essential than all the indicators $k_1, k_2, \ldots, k_m$, etc. This corresponds the instance where the lexico-graphical relation lex is employed when a comparison is made between the estimates of approaches. Now we give the definition of the above relation.

Let there be two vectors of estimates $\vec{v}, \vec{v}' \in V \subset R^m$. The lexico-graphical relation $\underset{\succ}{lex}$ is determined in the following way: the relation $\underset{\succ}{lex}$ occurs if and only if one the following conditions is satisfied.

$$
\begin{aligned}
&1)\ v_1^{'} > v_1^{''};\\
&2)\ v_1^{'} = v_1^{''}; v_2^{'} > v_2^{''}\\
&\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\\
&m)\ v_j^{'} = v_j^{''}, j = 1,2,\ldots,m-1, v_m^{'} > v_m^{''},\\
&v^{'} = (v_1^{'}, v_2^{'},\ldots,v_m^{'});\ v^{n} = (v_1^{n}, v_2^{n},\ldots,v_m^{n}).
\end{aligned}
$$

In this case the components $v_1, v_2, \ldots, v_m$, i.e. the estimates of the system quality indicators $k_1(\varphi), k_2(\varphi), \ldots, k_m(\varphi)$ are said to be strictly order in terms of their importance. As the relation $\vec{v}^{'} lex \vec{v}^{''}$ is satisfied they say that from the lexico-graphical stand point the vector $\vec{v}'$ is greater than the vector $\vec{v}'$. At $m-1$ the lexico-graphical relation coincides with the relation $\succ$ on the subset of real numbers.

In determining the lexico-graphical relation a major role is played by the order of enumerating quality indicators. The change in the numeration of quality indicators give rise to a different lexico-graphical relation.

3. Practical usage

Let us consider some practical peculiarities of an application of multicriteria optimization methods within a long-term and short-term planning, designing and controlling. In the examined examples of telecommunication networks operation and estimation of the quality indicators values is probed on mathematical models implemented on a computer using the packets of specific simulation modeling.

3.1 Telecommunication network variant choice

In particular, we considered features of an application of multicriteria optimization methods on the example of the packet switching network. For such a task the mathematical model of full-connected topology of a network was implemented. There was performed the simulation modeling of different variants of data transmission in the indicated network and the quality indicators estimates for each variant were obtained (Bezruk et al., 2008).

Pareto-optimal variants of the network were obtained with the methods of vector optimization and, among them, there was selected the single optimal variant of the network (fig. 1). The results of the optimization were used for the task of the network control when framing optimal control actions.

Thus, the control device collects the information on the current condition of the network and develops Pareto-optimal control actions which are directed to a variation of mechanisms of the arrival requests service and paths of packet transmission through the network.

The structure of the model, realized with a computer, includes simulators of the messages with a Poisson distribution and given intensities, procedures of the messages packing, their transmission through the communication channels. The procedures of the messages packing have simulated a batch data transmission with a mode of the window load control.

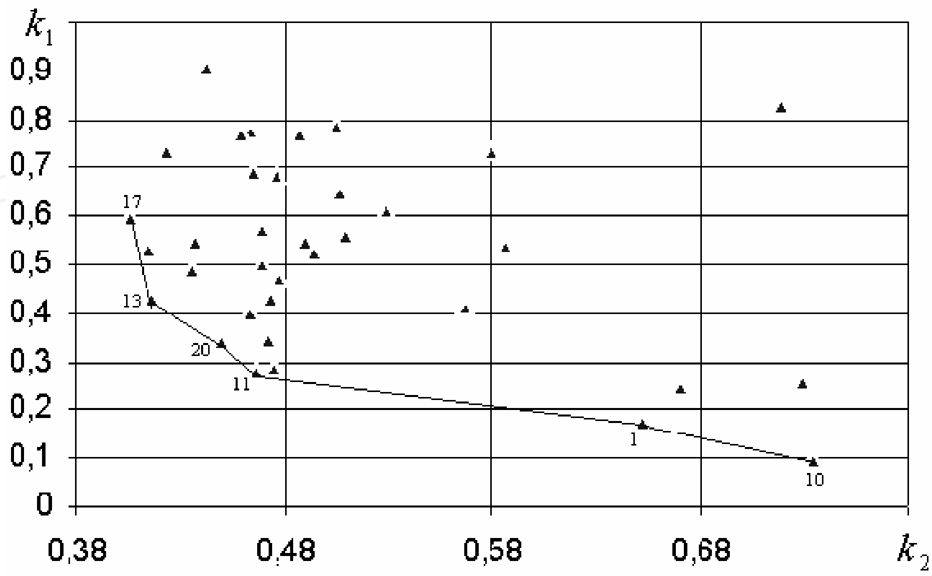


Fig. 1. Choice of Pareto-optimal variants of the telecommunication network.

The procedures of a packet transmission were simulated by the processes of transfer using duplex communication channels with errors. The simulation analysis of the transfer delays was stipulated at a packet transmission in the communication lines connected with final velocity of signals propagation in communication channels, fixed transmission channel capacity and packets arrival time in the queue for their transfer trough the communication channel.

Different variants of the telecommunication network functioning were realized at the simulation analysis, they differed in disciplines of service in the queues, ways of routing in a packet transmission and size of the window of the transport junction. In the considered example thirty six variants of the network functioning were obtained. Network functioning variants were estimated by the following quality indicators: average time of deliveries $k_1 = \overline{T}$ and average probability of message loss $k_2 = \overline{P}$. These quality indicators had contradictory character of interconnection. The obtained permissible set of network variants is presented in a criteria space (fig. 1). The subset of the Pareto-optimal network operation is selected by the exclusion of the inferior variants. The left low bound set of the valid variants corresponds to Pareto-optimal variants. Among Pareto-optimal variants of the network Φ_0 was selected a single variant from the condition of a minimum of the introduced resulting quality indicator $k_{pn} = C_1 k_1 + C_2 k_2$. For the case $C_1 = 0,4$, $C_2 = 0,6$ the single variant 11 was selected; the discipline service of the requests (in the random order) was established for it as well as the way of routing (weight method) and size of the “transmission window” (equal 8).

The given task is urgent for practical applications being critical to the delivery time (in telecommunication systems of video and voice intelligences, systems of the banking terminals, alarm installations, etc).

3.2 Multicriteria optimization in radio communication networks designing

Let us consider some practical aspects of multicriteria optimization methods when planning radio communication networks, on an example of cellular communication network (CCN). The process of finding CCN optimal variants includes such stages:

- setting the initial set of the system variants differed in the following terms: radio standards, the engaged frequency band, the number and activity of subscribers, covered territory, sectoring and the height of antennas, the power of base station transmitters, the parameter of radio wave attenuation, etc;
- separation of the permissible set of variants with regard of limitations on the network structure and parameters, limitation on the value of the quality indicators;
- choice of the subset of Pareto-optimal CCN variants;
- analysis of obtained Pareto-optimal CCN variants;
- choice of a single CCN variant.

In the considered example there was formed a set of permissible variants of CCN (GSM standard), which were defined by different initial data including the following ones: the planned number of subscribers in the network; dimensions of the covered territory (an area); the activity of subscribers at HML (hour of maximum load); the frequency bandwidth authorized for the network organization; sizes of clusters; the permissible probability of call blocking and percentage of the time of the communication quality deterioration.

The following technical parameters of CCN were calculated by a special technique.

1. The general number of frequency channels authorized for deployment of CCN in the given town, is defined as

$$N_k = \text{int}(\Delta F / F_k),$$

where F_k is the frequency band.

2. The number of radio frequencies needed for service of subscribers in one sector of each cell, is defined as

$$n_s = \text{int}(N_k / C \cdot M).$$

3. A value of the permissible telephone load in one sector of one cell or in a cell (for base stations incorporating antennas with the circular pattern) is defined by the following relationships

$$A = n_O\left[1-\sqrt{1-\left(P_{sl}\sqrt{\pi n_O / 2}\right)^{1/n_0}}\right] \text{ at } P_{sl} \le \sqrt{\frac{2}{\pi n_o}};$$

$$A = n_O + \sqrt{\frac{\pi}{2} + 2n_O \ln\left(P_{sl}\sqrt{\pi n_O / 2}\right)} - \sqrt{\frac{\pi}{2}} \text{ at } P_{sl} > \sqrt{\frac{2}{\pi n_o}},$$

where $n_0 = n_s \cdot n_a$; n_a is the number of subscribers which can use one frequency channel simultaneously. The value is defined by standard.

4. The number of subscribers under service of the base station, depending on the number of sectors, permissible telephone load and activity of subscribers

$$N_{aBTS} = M\,\mathrm{int}(A / \beta).$$

5. The necessary number of the base stations at the given territory of covering, is defined as

$$N_{BTS} = \mathrm{int}(N_a / N_{aBTS}).$$

where N_a is the given number of subscribers to be under service of the cellular communication network.

6. The cell radius, under condition that the load is uniformly distributed over the entire zone, is defined by the formula

$$R = \sqrt{\frac{1,21 \cdot S_0}{\pi N_{BTS}}}.$$

7. The value of the protective distance between BTS with equal frequency channels, is defined as

$$D = R\sqrt{3C},$$

and other parameters such as the necessary power at the receiver input, the probability of error in the process of communication session, the efficiency of radio spectrum use, etc.

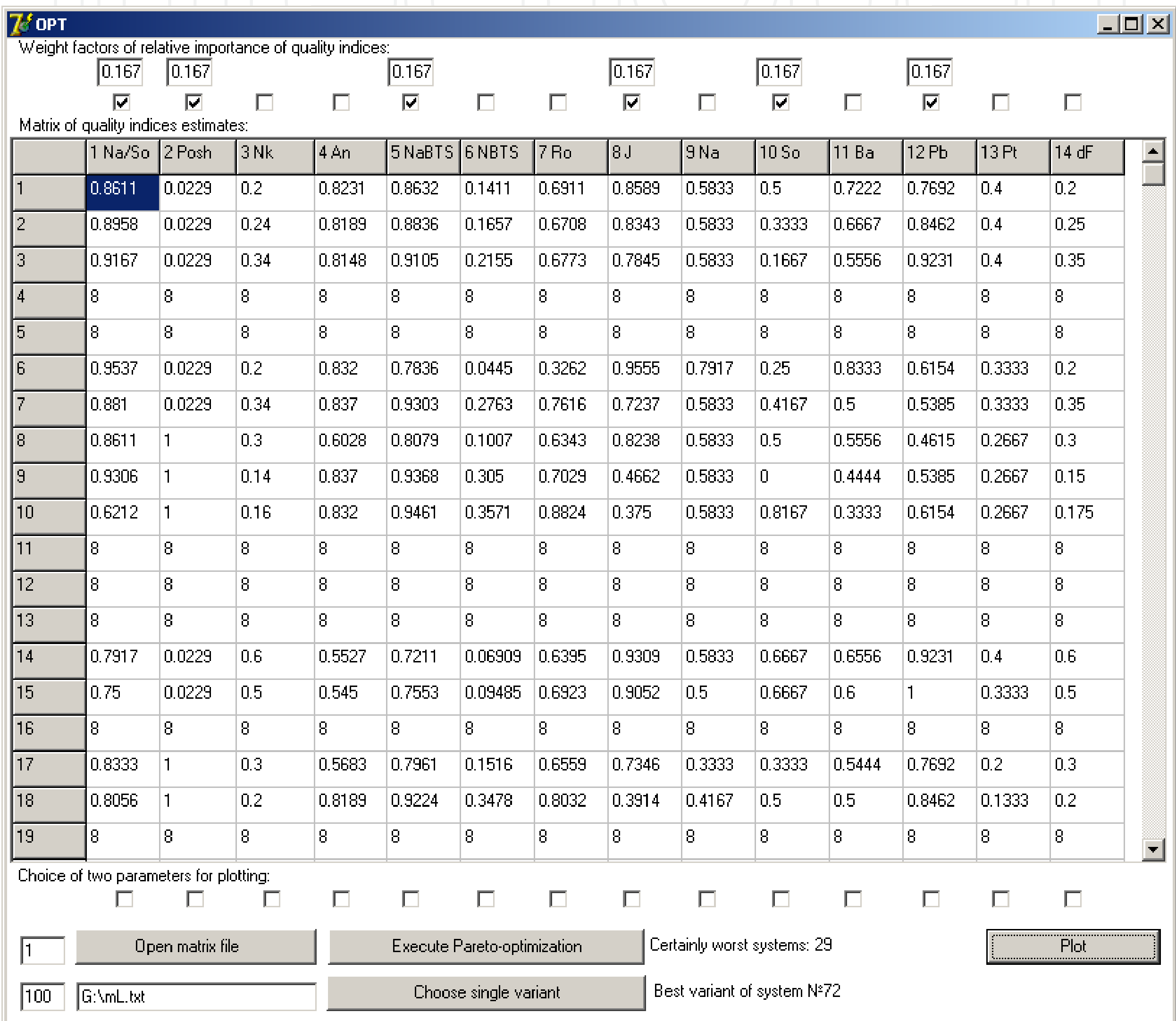
Finding the subset of Pareto-optimal network variants is performed in criteria space of the quality indicators estimates. A single variant of CCN was chosen with the use of the conditional criteria of preference by finding the extreme of the scalar criteria function as $c_i = \frac{1}{7},\ i = \overline{1,7}$.

For a choice of optimal design solutions on the basis of multicriteria optimization methods, there was developed the program complex. It includes two parts solving the following issues.

1. Setting initial data and calculation of technical parameters for some permissible set of variants of CCN.
2. A choice of Pareto-optimal network variants and narrowing them to a single one.

Fig. 2 shows, as an example, the program complex interface. Here is shown part of table with values of 14 indicators for 19 CCN variants. There is the possibility to choose («tick off») concrete quality indicators to be taken into account at the multicriteria optimization. Besides, here are given values of coefficients of relative importance of chosen quality indicators.

There was selected a subset of Pareto-optimal variants including 71 network variants. Therewith 29 certainly worst variants are rejected. From the condition of minimum conditional criteria of preference as of the Pareto subset, a single variant is chosen (№72). It is characterized by the following initial and calculated parameters: the number of subscribers is 30000; the area under service is 320 km^2; activity of subscribers is 0.025 Erl; the frequency bandwidth is 4 MHz; the permissible probability of call blocking is 0.01; percentage of the connection quality deterioration time is 0.07; the density of service is 94 active subscribers per km^2; the cluster size is 7; the number of base stations in the network is 133; the number of subscribers serviced by one BS is 226; the efficiency of radio frequency spectrum is $1.614 \cdot 10^{-4}$ active subscribers per Hz; the telephone load is 3.326 Erl; the probability of error is $5.277 \cdot 10^{-7}$; the angle of antenna radiation pattern is 120 degrees.



	1 Na/So	2 Posh	3 Nk	4 An	5 NaBTS	6 NBTS	7 Ro	8 J	9 Na	10 So	11 Ba	12 Pb	13 Pt	14 dF
1	0.8611	0.0229	0.2	0.8231	0.8632	0.1411	0.6911	0.8589	0.5833	0.5	0.7222	0.7692	0.4	0.2
2	0.8958	0.0229	0.24	0.8189	0.8836	0.1657	0.6708	0.8343	0.5833	0.3333	0.6667	0.8462	0.4	0.25
3	0.9167	0.0229	0.34	0.8148	0.9105	0.2155	0.6773	0.7845	0.5833	0.1667	0.5556	0.9231	0.4	0.35
4	8	8	8	8	8	8	8	8	8	8	8	8	8	8
5	8	8	8	8	8	8	8	8	8	8	8	8	8	8
6	0.9537	0.0229	0.2	0.832	0.7836	0.0445	0.3262	0.9555	0.7917	0.25	0.8333	0.6154	0.3333	0.2
7	0.881	0.0229	0.34	0.837	0.9303	0.2763	0.7616	0.7237	0.5833	0.4167	0.5	0.5385	0.3333	0.35
8	0.8611	1	0.3	0.6028	0.8079	0.1007	0.6343	0.8238	0.5833	0.5	0.5556	0.4615	0.2667	0.3
9	0.9306	1	0.14	0.837	0.9368	0.305	0.7029	0.4662	0.5833	0	0.4444	0.5385	0.2667	0.15
10	0.6212	1	0.16	0.832	0.9461	0.3571	0.8824	0.375	0.5833	0.8167	0.3333	0.6154	0.2667	0.175
11	8	8	8	8	8	8	8	8	8	8	8	8	8	8
12	8	8	8	8	8	8	8	8	8	8	8	8	8	8
13	8	8	8	8	8	8	8	8	8	8	8	8	8	8
14	0.7917	0.0229	0.6	0.5527	0.7211	0.06909	0.6395	0.9309	0.5833	0.6667	0.6556	0.9231	0.4	0.6
15	0.75	0.0229	0.5	0.545	0.7553	0.09485	0.6923	0.9052	0.5	0.6667	0.6	1	0.3333	0.5
16	8	8	8	8	8	8	8	8	8	8	8	8	8	8
17	0.8333	1	0.3	0.5683	0.7961	0.1516	0.6559	0.7346	0.3333	0.3333	0.5444	0.7692	0.2	0.3
18	0.8056	1	0.2	0.8189	0.9224	0.3478	0.8032	0.3914	0.4167	0.5	0.5	0.8462	0.1333	0.2
19	8	8	8	8	8	8	8	8	8	8	8	8	8	8

Fig. 2. Interface of program complex.

As results of Pareto-optimization, there were obtained multivariate patterns of exchange (MPE) of the quality indicators, being of antagonistic character. For illustration, some MPE are presented at fig. 3. Each MPE point defines the potentially best values of each indicator which can be attained at fixed but arbitrary values of other quality indicators. MPE also show how the improvement of some quality indicators is achieved at the expense of other.

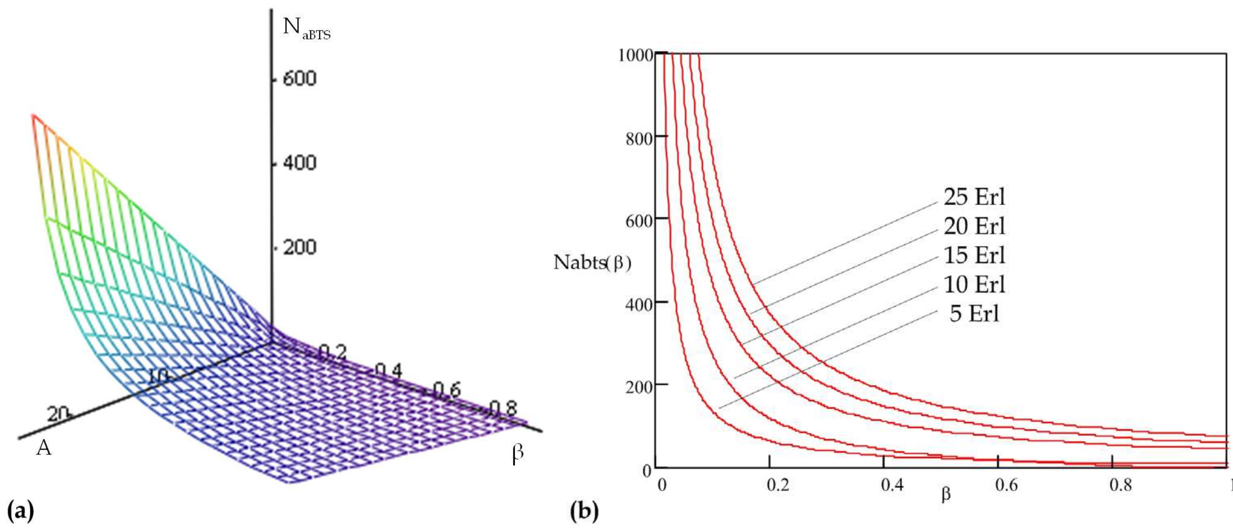


Fig. 3. MPE of the quality indicators (the number of subscribers serviced by one base station (a), the load, the activity of subscribers (b)) for CCN of GSM standard.

3.3 Features of a choice of Pareto-optimal routes

We have a set of permissible solutions (routes) on the finite network graph $G=(V,X)$, where $V=\{v\}$ – set of nodes, $E=\{e\}$ – set of network lines. Each route X is defined by a subset of the nodes and links. The goal task is presented by the model $\{X,F\}\rightarrow x^*$, where $X=\{x\}$ – set of permissible solutions (routes) on the network graph $G=(V,E)$; $F(x)$ – objective function of choice of the routes; x^* – optimal solution of the routing problem. The multicriteria approach of a choice of the best routes relies to perform decomposition of the function $F(x)$ to set (vector) partial choice functions. In this case on the set X it is given the vector of the objective function (Bezruk & Varich, 2011):

$$F(x)=(W_1(x),...,W_j(x),...,W_m(x)),$$

where components determine the values of quality routes indicators.

The route variant $x^*\in X$ is Pareto-optimal route if another route $x\in X$ doesn't exist, order to perform inequality $F_j(x^*)\leq F_j(\tilde{x}), j=1,...,m,$ where at least one of the inequalities is strict. We propose to solve the problem of finding Pareto-optimal routes by using weight method. It is used for finding extreme values of the objective route function as a weighted sum of the partial choice functions for all possible values of the weighting coefficients λ_j :

$$\underset{\text{var}\, x\in X}{\text{extr}}=(F(x))=\sum_{j=1}^{m}\lambda_j W_j(x).$$

Pareto-optimal routes have some characteristic features. Particularly, Pareto-optimal alternative routes corresponds to the Pareto coordinated optimum partial objective functions $W_1(x),\ldots,W_j(x),\ldots,W_m(x)$. When selecting a subset of the Pareto-optimal routes there was dropped a certainly worst variant in terms of the absolute criteria of preference.

Pareto-optimal alternatives of the routes are equivalent to the Pareto criteria and could be used for organizing multipath routing in the multi-service telecommunication networks.

Network model consists of twelve nodes; they are linked by communication lines with losses (fig. 4).

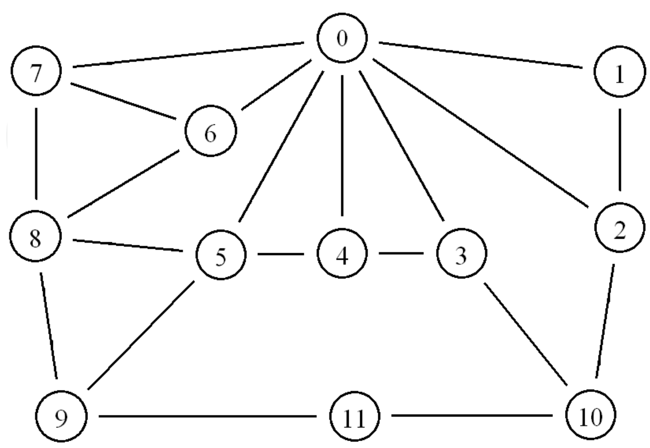


Fig. 4. The structure of the investigated network.

The quality indicators normalized to maximum values are presented in table 2.

The link	The delay time of packets transmission k_1	The level of packet loss k_2	The cost of using the line k_3
0-1	0.676	1	0.333
0-2	1	0.25	1
0-3	0.362	1	0.333
0-4	0.381	0.25	1
0-5	0.2	1	0.333
0-6	0.19	1	0.333
0-7	0.571	0.25	1
7-6	0.4	0.25	0.333
7-8	0.362	0.25	0.667
8-6	0.314	0.5	0.5
8-5	0.438	0.25	0.333
8-9	0.248	0.5	0.333
9-5	0.257	0.25	1
9-11	0.571	0.25	0.667
11-10	0.762	0.25	0.333
5-4	0.381	0.25	0.667
2-10	0.457	0.25	0.333
3-10	0.79	0.25	0.333
4-3	0.286	0.25	0.333
1-2	0.448	0.25	0.333

Table 2. Network quality indicators.

Network analysis shows that for each destination node there are many options to choose the route directly. For example, between node 0 and node 8 there are 22 routes.

Fig. 5 shows the set of the alternative routes between nodes 0 and 8 in the space of the quality indicators k_1 and k_2. Subset of the Pareto-optimal alternatives routes corresponds to the left lower border which includes three variants, they are marked (▲). This subset corresponds to be coordinated in Pareto optimum of the quality indicators.

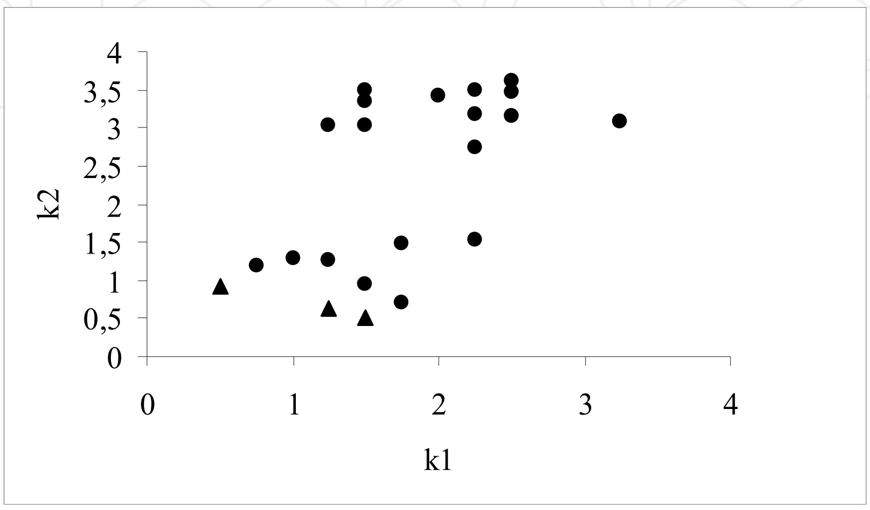


Fig. 5. Set of the routes between nodes 0 and 8.

The resulting subset of the Pareto-optimal alternative routes can be used for organizing multipath routing when using MPLS technology. It will allow to provide a load balancing and a traffic management and to provide given quality-of-service taking into account the set of the quality indicators.

3.4 Pareto-optimal choice of the speech codec

Proposed theoretical investigations can be used for Pareto-optimal choice of the speech codec used in IP-telephony systems (Bezruk & Skorik, 2010).

For carrying out the comparative analysis of basic speech codec and the optimal codec variant choice there have been used the data about 23 speech codecs described by the set of the technical and economic indicators: coding rate, quality of the speech coding, complexity of the realization, frame size, total time delay, etc. The initial values of the quality indicators are presented in table 3. It is easy to see that presented quality indicators are connected between each other with competing interconnections.

The time delay is increasing with frame size increasing as well as with complexity of the coding algorithm realization. Then, when transferring speech the permissible delay can not be bigger than 250 ms in one direction.

A frame size influences on the quality of a reproduced speech: the bigger is the frame, the more effective is the speech modeled. On other hand, the big frames increase an influence of the time delay on processing the information transferring. A frame size is defined by the compromise amongst these requirements.

№	Codec	Speech coding, kbps	Coding quality, MOS (1-5)	Complexity of the realization, MIPS	Frame size, ms	Total delay, ms
1	G 711	64	3,83	11,95	0,125	60
2	G 721	32	4,1	7,2	0,125	30
3	G 722	48	3,83	11,95	0,125	31,5
4	G 722(a)	56	4,5	11,95	0,125	31,5
5	G 722(b)	64	4,13	11,95	0,125	31,5
6	G 723.1(a)	5,3	3,6	16,5	30	37,5
7	G 723.1	6,4	3,9	16,9	30	37,5
8	G 726	24	3,7	9,6	0,125	30
9	G 726(a)	32	4,05	9,6	0,125	30
10	G 726(b)	40	3,9	9,6	0,125	30
11	G 727	24	3,7	9,9	0,125	30
12	G 727(a)	32	4,05	9,9	0,125	30
13	G 727(b)	40	3,9	9,9	0,125	30
14	G 728	16	4	25,5	0,625	30
15	G 729	8	4,05	22,5	10	35
16	G 729a	8	3,95	10,7	10	35
17	G 729b	8	4,05	23,2	10	35
18	G 729ab	8	3,95	11,5	10	35
19	G 729e	8	4,1	30	10	35
20	G 729e(a)	11,8	4,12	30	10	35
21	G 727(c)	16	4	9,9	0,125	30
22	G 728(a)	12,8	4,1	16	0,625	30
23	G 729d	6,4	4	20	10	35

Table 3. Codecs characteristics.

Complexity of the realization is connected with providing necessary calculations in real time. The coding algorithm complexity influences on the physical size of coding, decoding or combined devices, and also on its cost and power consumption.

In table 4 are presented some transformations results of the initial values of the quality indicators. In particular, there were performed the rationing operations of the indicators to their maximum values $k_{iн} = \frac{k_i}{k_{i\max}}$. These indicators were transformed to a comparable kind where all indicators had the same character depending on the technical codecs characteristics. In particular, for indicators k_{3n} and k_{5n} the transformations $k'_{3н} = \frac{1}{k_{3н}}$, $k'_{5н} = \frac{1}{k_{5н}}$ were done.

№	Codec	K_{1n}	K_{2n}	K'_{3n}	K_{4n}	K'_{5n}	Pareto-optimal choice
1	G 711	1	0,851	0,604	0,004	0,515	-
2	G 721	0,5	0,911	1	0,004	1	+
3	G 722	0,75	0,851	0,604	0,004	0,969	-
4	G 722(a)	0,875	1	0,604	0,004	0,969	+
5	G 722(b)	1	0,918	0,604	0,004	0,969	+
6	G 723.1(a)	0,083	0,8	0,439	1	0,818	+
7	G 723.1	0,1	0,867	0,424	1	0,818	+
8	G 726	0,375	0,822	0,748	0,004	1	-
9	G 726(a)	0,5	0,9	0,748	0,004	1	-
10	G 726(b)	0,625	0,866	0,748	0,004	1	+
11	G 727	0,375	0,822	0,727	0,004	1	-
12	G 727(a)	0,5	0,9	0,727	0,004	1	-
13	G 727(b)	0,625	0,866	0,727	0,004	1	-
14	G 728	0,25	0,889	0,281	0,021	1	+
15	G 729	0,125	0,9	0,317	0,333	0,879	+
16	G 729a	0,125	0,878	0,669	0,333	0,879	+
17	G 729b	0,125	0,9	0,309	0,333	0,879	-
18	G 729ab	0,125	0,878	0,626	0,333	0,879	-
19	G 729e	0,125	0,911	0,237	0,333	0,879	-
20	G 729e(a)	0,184	0,915	0,237	0,333	0,879	+
21	G 727(c)	0,25	0,889	0,727	0,004	1	-
22	G 728(a)	0,2	0,911	0,453	0,021	1	+
23	G 729d	0,1	0,889	0,359	0,333	0,879	+

Table 4. Transformed quality indicators.

On the base of received results there were considered the practical application features examined methods of the allocation of the Pareto-optimal speech codec variant set taking into account a set of the quality indicators as well as the unique design decision choice. From the initial set of the 23 speech codecs variants there was allocated the Pareto subset included 12 codecs variants (marked + in table 4).

The only one project decision was chosen from the condition of the scalar goal function extreme (9) with two different values of β defined characters of this function changing. In table 5 are presented the values of the given function for Pareto-optimal speech codecs variants at $\beta = 2$ and $\beta = 3$. It was obtained that an extreme goal function value, depending on β, is reached for the same speech codec G 722 (b).

Within statement of a problem we have chosen the codec of series G.722b which has following values of the quality indicators: speech coding – 64 kbps, coding quality – 4,13 MOS, complexity of the realization – 11,95 MIPS, the frame size – 0,125 ms, total delay – 31,5 ms.

№	Codec	Values $\xi_{\vec{k}}$ for diffrent β	
		$\beta = 2$	$\beta = 3$
2	G 721	0,35099	0,24688
4	G 722(a)	0,35039	0,28188
5	G 722(b)	0,35476	0,28532
6	G 723.1(a)	0,31677	0,25791
7	G 723.1	0,32312	0,26308
10	G 726(b)	0,32863	0,26445
14	G 728	0,27801	0,24056
15	G 729	0,26904	0,22785
16	G 729a	0,29103	0,23837
20	G 729e(a)	0,26912	0,22898
22	G 728(a)	0,28812	0,24582
23	G 729d	0,26927	0,22716

Table 5. Results of multicriteria optimization.

3.5 Network resources controlling

Let us consider some features of the short-term planning issues in the telecommunication system. There was shown the important place of multi-service network occupied with models, methods and facilities of network resources controlling in modern and perspective technologies. To the basic network resources facilities belong: channel resources control facilities (channels throughput, buffers size, etc), information resources control (user traffic).

Considered system was presented as the model of a distributed telecommunication system, consisting from a set of operating agents, for each autonomous system (fig 6).

In this model the process of network resources control was carried out by finding the distribution streams vector of the following type (Bezruk & Bukhanko, 2010):

$$\vec{K} = (k_1, k_2, \ldots, k_l), \ \sum_{i}^{l} k_i = 1,$$

with next limitation

$$0 \le k_i \le 1, \ i = \overline{1 \ldots l};$$

$$\lambda_i^{out} k_i \le c_i, \ i = \overline{1 \ldots l}.$$

Each element of this vector characterizes a part of outgoing user traffic from autonomous system operating agent transferred by using a corresponding channel. Within a given model, the task of network resources controlling comes to solving the optimization problem connected to function minimization.

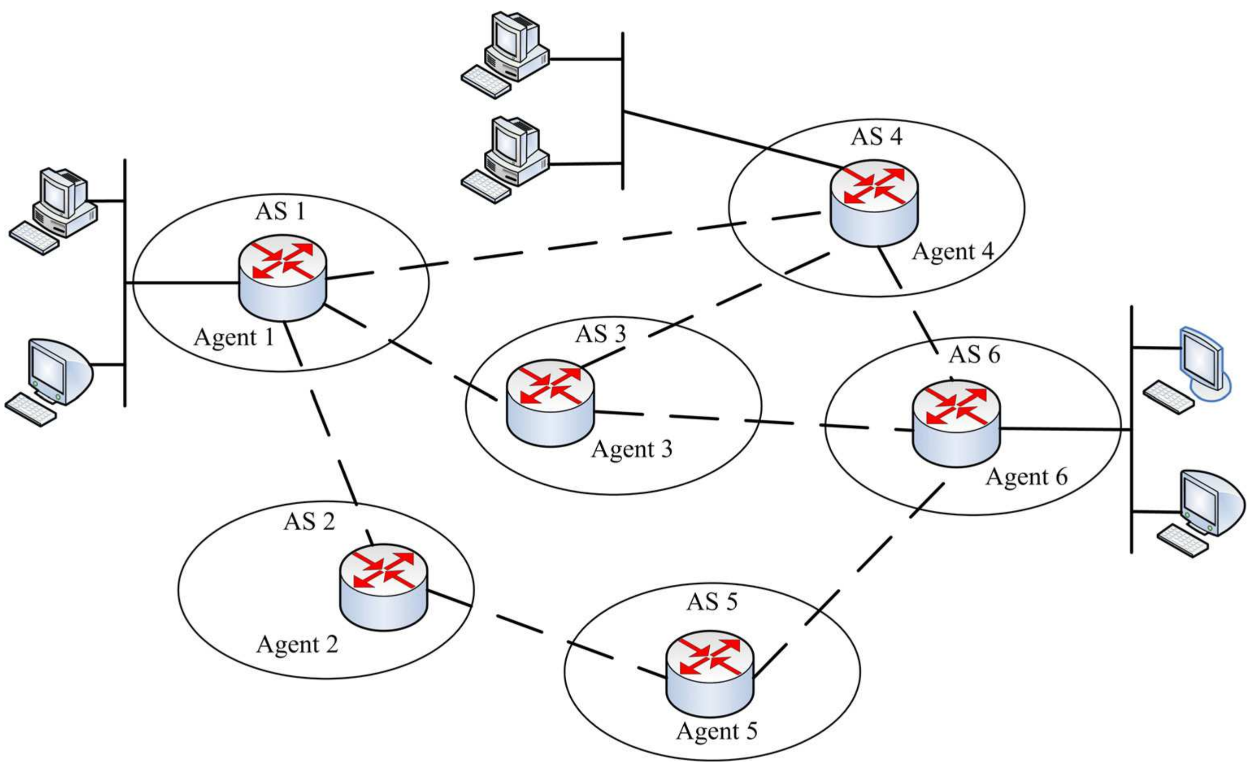


Fig. 6. Considered telecommunication system.

$$\varepsilon(\vec{K}) = \min(q_1\Phi + q_2\sigma_1(\vec{K}) + q_3\sigma_2(\vec{K})), \tag{10}$$

where $\sigma_1(\vec{K})$ – standard deviation of channels loading x_i, $i = \overline{1...l}$;

$$\sigma_1(\vec{K}) = \sqrt{\frac{1}{l-1}\sum_{i=1}^{l}\left(x_i - \bar{x}\right)^2};$$

$\sigma_2(\overline{K})$ – standard deviation of agents loading Z_i, $i = \overline{1...l}$;

$$\sigma_2(\vec{K}) = \sqrt{\frac{1}{l\text{-}1}\sum_{i=1}^{l}\left(Z_i - \bar{Z}\right)^2};$$

Φ – used routing protocol metric;

$$\Phi = \sum_{i=1}^{l}\varphi_i x_i;$$

φ_i – cost of full used channel ($\sum\lambda_i = c_i$);

q_1, q_2, q_3 – weight coefficients characterized the traffic balancing cost using standard metric, agents and channels loading.

The considered mathematical model of the distributed network resources controlling uses specific criteria of optimality included standard routing protocol metrics, a measure of channels and agents loading in given telecommunication network.

Obviously, under condition of $\sigma_1(\vec{K})$ and $\sigma_2(\overline{K})$ absence, function (10) becomes the model of the load balancing under the routes with equal or non-equal metric. However, absence of the decentralized control behind the autonomous system of telecommunication network can finally result in an uncontrollable overload. That fact is defined by the presence of additional minimized indicators leading to the practical value of the proposed model. Thus a choice of the relation of weight coefficients q_1, q_2 and q_3 is an independent problem demanding some future investigations and formalizations. In this model this task was dared with expert's estimations.

The proposed imitation model included up to 18 agents (fig. 7). Researches for different variants of connectivity between agents have been carried out.

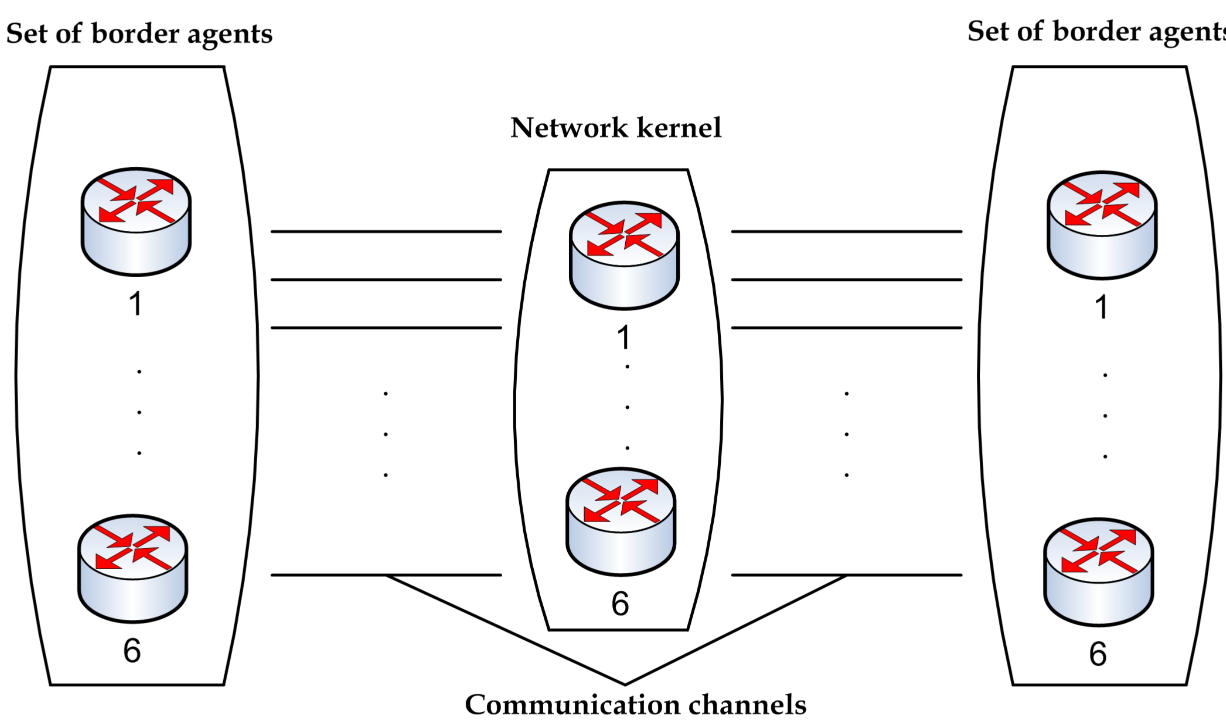


Fig. 7. Used imitation model.

During practical investigation there were analyzed several models of multipath routing and load balancing. These models are listed below:

M1 – model of routing by RIP;
M2 – model of multipath routing by an equal metric;
M3 – model of multipath routing by an non-equal metric (IGRP);
M4 – Gallagher stream model;
M5 – considered model with multicriteria account of two indicators (10);
M6 – considered model with multicriteria account of three indicators (10).

Below are presented some results of the analytic and imitation modeling within comparative analysis of considered existing and proposed models. These results are shown as dependences of the blocking probability and average delay time from the network loading (fig. 8).

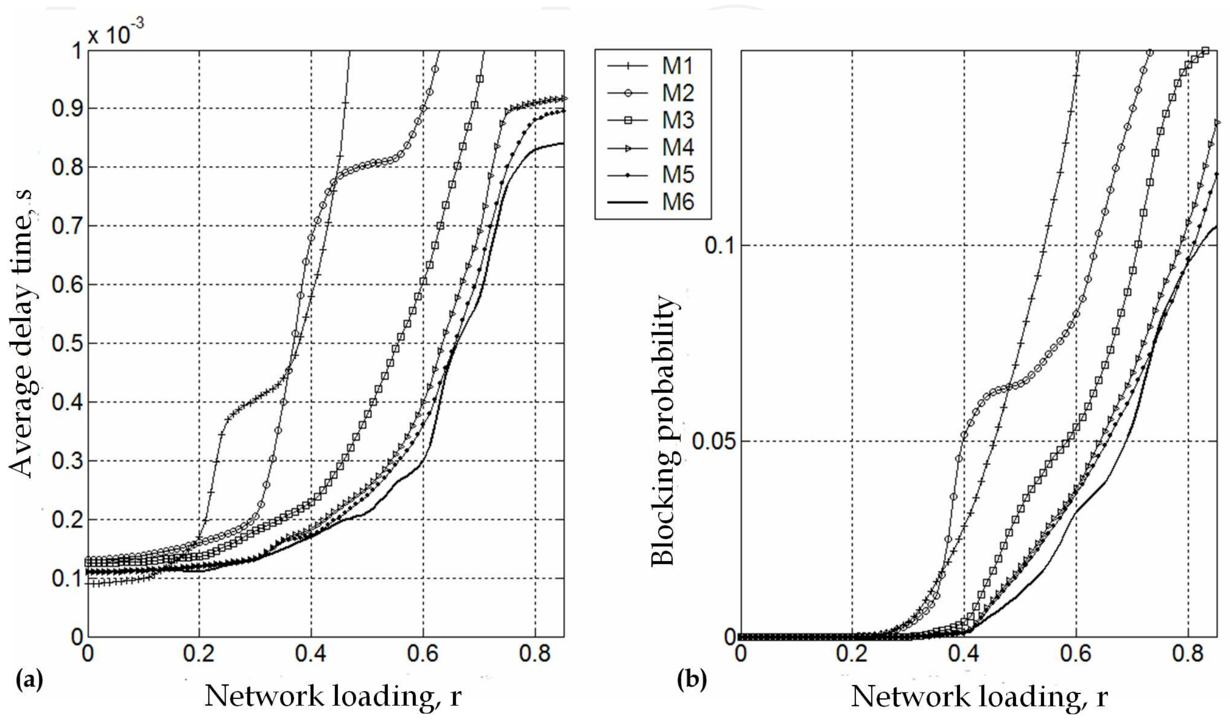


Fig. 8. Received dependences of average delay time (a) and blocking probability (b).

The use of the proposed models allows to:

- lower the average delay time (a) in comparison with the best known model (M4), for 3 – 12% (M5) and for 6 – 25% (M6);
- lower the general blocking probability (b) for 6 – 11% (M5) and 6 – 20% (M6).

4. Conclusion

The present work deals with the methodology of generating and selecting the variants of information systems when they are optimized in terms of the set of quality indicators. The multicriteria system-optimization problems are solved in three stages. By using the morphological approach a structural set of permissible variants of a system is initially generated. This set is mapped into the space of vector estimates. In this space a subset of Pareto-optimal estimates is selected, defining the potential characteristics of the system on the basis of the set of quality indicators. At the conclusive stage the only variant is selected amongst the Pareto-optimal variants of the system provided there exists an extreme of a certain scalar functional whose form is determined with the use of some additional information obtained from a customer.

Multicriteria optimization issues and methods based on Pareto conclusions are introduced for the long-term and short-term practical planning, designing and controlling within different types of telecommunication networks. In the process of solving the optimization problems we consider the set of network quality indicators as the different network topologies, transmission capacities of communication channels, various disciplines of service requests applied to different routing ways, etc.

Peculiarities of the long-term multicriteria optimization methods used for solving problems of the cellular networks planning are considered. As an example, the Pareto-optimization solution within planning of the cellular communication networks is also presented.

Practical features of the multicriteria approach in solving the optimal routing problem in the multi-service networks are considered within organizing multipath routing as well as speech codec choice based on a set of the quality indicators. The model of the information resources balancing on a basis of the decentralized operating agents system with a multicriteria account of chosen quality indicators is also offered. Considered adaptive balancing traffic algorithm improves the basic characteristics of the telecommunication network in a process of the short-term controlling for chosen cases of topologies.

5. Acknowledgment

The research described in this work was made possible in part by the scientific direction "Telecommunication and information networks optimization", headed by prof. Bezruk V., of the Communication Network Department within Kharkov National University of Radio Electronics, Ukraine.

6. References

Bezruk, V. & Skorik, Y. (2010). Optimization of speech codec on set of indicators of quality. *Proceedings of TCSET'2010 Modern problems of radio engineering, telecommunications and computer science,* p. 212, ISBN 978-966-553-875-2, Lviv – Slavske, Ukraine, February 23 – 27, 2010

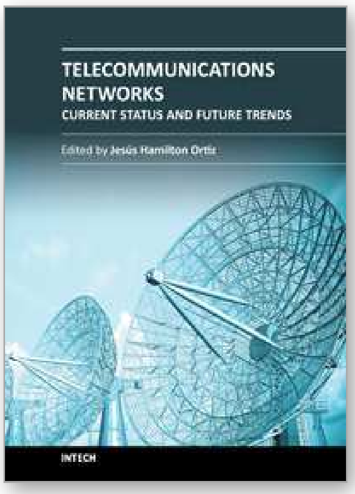
Bezruk, V. & Bukhanko, O. (2010). Control mode of network resources in multiservice telecommunication systems on basis of distributed system of agents. *Proceedings of CriMiCo'2010 Microwave and Telecommunication Technology*, pp. 526-527, ISBN 978-966-335-329-6, Sevastopol, Crimea, Ukraine, September 13 – 17, 2010

Bezruk, V. & Varich, V. (2011). The multicriteria routing problem in multiservice networks with use composition quality indicators. *Proceedings of CriMiCo'2011 Microwave and Telecommunication Technology,* pp. 519 – 520, ISBN 978-966-335-254-8, Sevastopol, Crimea, Ukraine, September 12 – 16, 2011

Figueira, J. (Ed(s).). (2005). *Multiple Criteria Decision Analysis: State of the Art Surveys*, Springer Science + Business Media, Inc, ISBN 978-0-387-23081-8, Boston, USA

Saaty, P. (2005). *Theory and Applications of the Analytic Network Process: Decision Making with Benefits, Opportunities, Costs and Risks,* RWS Publications, ISBN 1-888603-06-2, Pittsburgh, USA

Taha, H. (1997). *Operations Research: An Introduction*, Prentice Hall Inc., ISBN 0-13-272915-6, New Jersey, USA



Telecommunications Networks - Current Status and Future Trends

Edited by Dr. Jesús Ortiz

ISBN 978-953-51-0341-7
Hard cover, 446 pages
Publisher InTech
Published online 30, March, 2012
Published in print edition March, 2012

This book guides readers through the basics of rapidly emerging networks to more advanced concepts and future expectations of Telecommunications Networks. It identifies and examines the most pressing research issues in Telecommunications and it contains chapters written by leading researchers, academics and industry professionals. Telecommunications Networks - Current Status and Future Trends covers surveys of recent publications that investigate key areas of interest such as: IMS, eTOM, 3G/4G, optimization problems, modeling, simulation, quality of service, etc. This book, that is suitable for both PhD and master students, is organized into six sections: New Generation Networks, Quality of Services, Sensor Networks, Telecommunications, Traffic Engineering and Routing.