MULTICRITERIA OPTIMIZATION IN TELECOMMUNICATION NETWORKS PLANNING, DESIGNING AND CONTROLLING

Bezruk V.M., Bukhanko O.M.
Kharkov National University of Radio Electronics
Communication Networks Department, 14, Lenin Ave., 61166, Kharkov
Tel. (057) 702-14-29, E-mail: bezruk@kture.kharkov.ua

Some features of methodology of telecommunication networks optimal design variants choice taking into account of the quality indicators are represented. In the presented work multycriteria optimization methods application in planning of cellular networks, optimal routing, choice of speech codec, controlling network resources are given too.

Introduction. The optimal problem solution of planning, designing and controlling in telecommunication networks involves definition of the initial set of the decisions, formation of a subset of the system acceptable variants, definition a criterion of optimality, and also the choice of variants of structure and network parameters, optimal by particular criterion. It is the tasks of a general decision making theory, which are reduced to implementation of some choice function of the best (optimal) system on the valid variants set. At an optimum variants choice taking into account the set of quality indicators methods we have used multicriteria optimization.

The initial set of acceptable variants of a telecommunication network is formed through the definition of different network topologies, transmission capacities of communication channels, various disciplines of service requests, applied to different routing ways choices etc. The obtained variants of a telecommunication network construction are estimated on a totality of given metrics describing the information transmission quality. Thus, the formed set of the acceptable design decisions is represented in the space of criteria ratings of quality indicators, where with usage of unconditional criterion of preference, the subset of effective (Pareto-optimal) variants of the telecommunication network is selected.

This short paper discusses some theoretical and practical aspects of the multicriteria optimization application in telecommunication networks planning, designing and controlling. It considers the particularities of application of the methods of multicriteria optimization at operation management of the telecommunication systems.

Methods of Pareto-optimal systems finding. In the general case, a telecommunication network is the system that may be considered as an ordered set of elements, relations and their properties. Their unique setting defines the goal searching system.

The solution of the problem of a choice of the system optimal variants includes the following stages: formation of a set of the system admissible variants, setting of a combination of quality indicators of the system optimality, as well as a choice of the best variants of the system by the given criterion of optimality. Let's consider some features of the methodology of the telecommunication network optimal design variants choice taking into account the quality indicators. The assigned limits on the operation conditions, $s \in S_\partial$ structure and $\beta \in \mathrm{B}_\partial$ parameters of the telecommunication networks define a subset of $\Phi_\partial = S_\partial \times \mathrm{B}_\partial$ acceptable variants. When introducing the criterion of an optimality of a network there are two approaches: ordinal and cardinal. Ordinal approach appeals to the order (better - worse) and is based on the introduction of some binary relations of admissible alternatives set. The decision $\phi^{(o)} \in \Phi_\partial$ is named optimal under the ratio $\succ$, if other decisions $\phi \in \Phi_\partial$ do not exist, for which the ratio $\phi \succ \phi^{(o)}$ is fair. The set of all optimal decisions under the ratio $\succ$ is indicated through $opt_\succ \Phi_\partial$. The cardinal approach to the description of preferences assigns to each alternative $\phi \in \Phi_\partial$ some numerical value of the function $U(\bullet)$, defining usefulness of alternative ϕ. Each utility function defines the appropriate order (or preference) R on set Φ_∂ ($(\phi' R \phi'')$) when and only when $U(\phi') \geq U(\phi'')$. In this case they say that the utility function $U(\bullet)$ is the indicate of preference R.

It is impossible to set scalar criterion of an optimality resulting in to choice of the single variant of solution $\phi^{(o)} = \underset{\phi\in\Phi_\partial}{opt}\left[U(\phi)\right]$ in a number of cases due to poor prior representations about optimality of a network in the formalized form. Therefore on the initial stages of planning the network is characterized by a totality of quality index and bound with them by the vector goal function

$$\vec{k}(\phi) = (k_1(\phi),\ldots,k(\phi)) . \quad (1)$$

In this case, there occur problems of solutions optimization by a set of quality indicators, which are also called the problems of multi-criterion or vector optimization. As a result of such a solution of the problems, there is found the subset of effective (Pareto-optimal) variants of the system, containing in the general case not one but several variants non-dominated by the relation of the strict preference.

The Pareto-optimal network versions design solution can be derived immediately on $\Phi_{\ddot{a}}$ set with application of introduced binary preference relations. This subset of Pareto-optimal variants of a network can be found as well in the space of introduced quality indicators (1), which are also named the criterion space of estimates

$$V = \vec{K}(\Phi_\partial) = (\vec{v} \in R^m \left| \vec{v} = (k_1(\phi), k_2(\phi),\ldots \right.$$
$$\ldots, k_m(\phi)), \quad \phi \in \Phi_\partial).$$

Here to each design solution ϕ corresponds its estimate of chosen quality indicators $\vec{v} = \vec{k}(\phi)$ and, vice versa, to each estimate corresponds the design solution (in the general case, not necessarily one solution).

The Pareto-optimal design solutions can be found either directly or with the use of special methods, for example, of the weight method, or of the method of operating characteristics.

$$\underset{\phi\in\Phi_\partial}{opt}\left[k_p(\phi) = \lambda_1 k_1(\phi) + \lambda_2 k_2(\phi) + \ldots + \lambda_m k_m(\phi)\right]; \quad (2)$$

$$\underset{\phi\in\Phi_\partial}{opt}\left[k_1(\phi)\right], \quad k_2(\phi) = K_{2\phi};\ k_3(\phi) = K_{3\phi},\ldots,k_m(\phi) = K_{m\phi}; \quad (3)$$

where $\lambda_1, \lambda_2,\ldots,\lambda_m$ are chosen from the condition $\lambda_i > 0, \quad \sum_{i=1}^{m} \lambda_i = 1$;

$K_{2\phi}, K_{3\phi},\ldots,K_{m\phi}$ – some fixed, but arbitrary values of quality indicators.

Practical usage of multycriteria optimization methods. 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.

Planning radio communication networks. Let us consider some practical particularities of application of multicriteria optimization methods, when planning radio communication networks, on an example of cellular communication network (CCN) [1].

In the considered example, there were formed a set of admissible variants of CCN of GSM standard, which were defined by different quality indicators. The finding of the subset of Pareto-optimal variants of networks is performed in criterion space of quality indicators estimates with use of unconditional criterion of preference. A single variant of the set of Pareto-optimal CCN was chosen using of the conditional criterion of preference by finding the extreme of the scalar criterion function at $c_i = \frac{1}{7},\ i = \overline{1,7}$.

As a result of Pareto-optimization, there are obtained multivariate patterns of exchange (MPE) of quality indicators being of antagonistic character. For illustration, some MPE are presented in fig. 1. Each MPE point defines the potentially best values of each index 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 indicators.

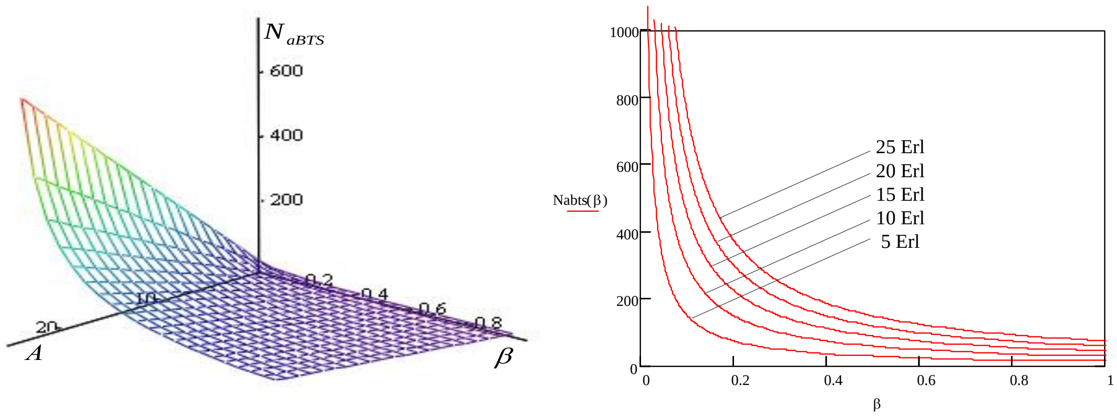

Fig. 1. MPE of quality indicators (the number of subscribers serviced by one base station, the load, the activity of subscribers) for CCN of GSM standard

Choice of speech codecs. At creation of networks of an IP-telephony there is a necessity of a choice of speech codecs, optimum taking into account set of indicators of quality [2].

For carrying out of the comparative analysis of speech codecs and a choice of optimum variants data about 23 speech codecs are taken. For their description it was used the set of 5 technical and economic indicators: speed of the coding, an estimation of quality of the coding of speech, complexity of realisation, the size of a shot, a total delay. Indicators of quality of speech codecs are connected among themselves and have competing character. From initial set of admissible variants of speech codec subset of Pareto including 23 variants of codecs is allocated. The unique design decision got out of a condition of an extreme of the scalar criterion function constructed on the basis of the theory of dim sets.

It is received, that at the set statement of a problem by the optimum speech codec the codec of series G.722b which has following values of indicators of quality: speed of coding – 64 kbit/with, an estimation of quality of coding of speech – 4,13 MOS, complexity of realisation – 11,95 MIPS, the size of a shot – 0,125 ms, a total delay – 31,5 ms.

Choosing optimal routes. The increasing volume and diversity of traffic, its demands to the quality of transmission in multiservice networks determine the need for new approaches to their management. Currently, there are a large number of routing algorithms, implemented on different principles. These algorithms solve the problem of choosing optimal routes, as a rule, taking into account one of the indicators of quality. Therefore, in modern multiservice networks raises the problem of the totality of the performance network to provide the specified quality of service requirements of different types of traffic. This determines the need for multicriteria optimization methods on networks for solving the routing [3].

In this work practical features of the application of the multicriteria approach to the decision of a problem of the optimal routing on an example of a fragment of a network of the Kharkov town are considered. For a finding of a subset of Pareto-optimum decisions it is offered to use a weight method (2).

Management of networking channel's and information resources. Multicriteria optimization could be also used in a management of networking channel's and information resources. Within existing telecommunication technologies for the solving of existing problems with the network resources controlling the protocols routing and load balancing, means, algorithms service and restrictions queues is engaged. Network resources' balancing is provided on the basis of the vector of traffic distribution [4]

$$\vec{K} = (k_1, k_2, \ldots, k_l), \quad \sum_{i}^{l} k_i = 1. \qquad (4)$$

Within this model the network resources controlling comes to the optimization task depended with function (5) minimization. This model takes into account the standard routing metric, the standard deviation of channels and controlling agents loading

$$\varepsilon(\vec{K}) = \min(q_1\Phi + q_2\sigma_1(\vec{K}) + q_3\sigma_2(\vec{K})). \qquad (5)$$

According to investigations it can be concluded that according to changing network loading within the proposed model is able to minimize the delay time for 3 – 12% and 6 – 25%, the probability of packet loss on 6 – 11% and 6 - 20%, respectively for both methods of (5) minimization.

Optimal functioning system variant. Pareto-optimal variants of the network are obtained with the methods of vector optimization. Among them the single optimal variant of construction of a network is selected for the task of planning (fig. 2). Results of optimization were used for the task of the network control when framing optimal control actions. In the example the centralized-distributed control structure – the load control mechanism in a communication channel is implemented in each switching centre [5].

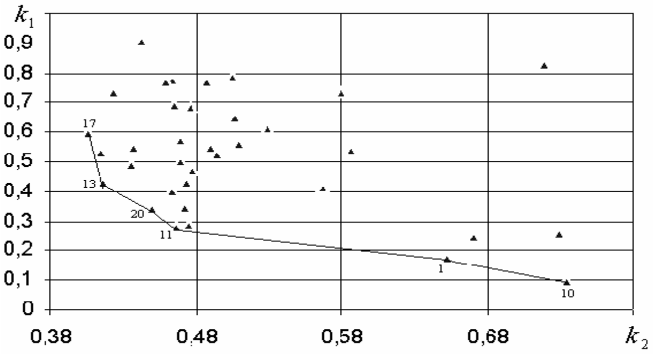

Fig. 2. Choice of Pareto-optimal variants of the telecommunication network

The quality indicators - time of delivery and probability of loss of packets are selected from the surveyed example at datagram message transmission. The given task is urgent for practical applications critical to time of the messages delivery (in telecommunication systems of video and voice intelligences, systems of banking terminals; alarm installations; systems of fault recovery on telecommunication networks).

Conclusions. The structure of the model realized with a computer, includes simulators of the messages with a Poisson distribution law and given intensities, procedures of the messages packing, their transmission by the communication channels.

The methods of the multicriteria optimization of the processes of planning and controlling the telecommunication networks in present issue considered above. They can be used when starting, upgrading both operation of analog and digital networks, cellular networks and multiservice networks, satellite networks, local and corporate networks.

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