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SERVICE MODEL OF THE VOICE TRAFFIC IN MULTIPROTOCOL LABEL SWITCHING NETWORKS

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This paper proposes and investigates a service model of the voice traffic in multiprotocol label switching networks. The study of Multiprotocol label switching networks (MPLS) requires a formal description of processes occurring in them, development of mathematical models, reflecting main properties of the investigated object and allows calculating the values in the required operating mode. In this paper, we develop the model of functioning MPLS network in the form of a multi-phase, multi-channel, open-loop system. We propose analytical expressions describing the process of mutual influence when servicing requests of various communication directions. To determine parameters of quality of service quality and bandwidth channels MPLS network, necessary compare them with the values of normed and assess the compliance of the specified standards.

Introduction

The concept of constructing next-generation communication networks (NGN) defines the perspective for development and construction of networks, which will be competitive in the telecommunications market in the near future. Many experts note that technologies used in the network NGN should meet the following basic requirements [1, 2]:

1. IP based Protocol.
2. Ensure collaboration with networks built earlier, and especially with networks ATM present in large quantities in the telecommunications market of many developed countries.
3. Maintain preset indicators of service quality in networks using a variety of technologies.
4. To ensure the high performance of equipment, especially on highways network.
5. To guarantee required values of the delay and jitter when servicing the real-time load and others.

Problem statement

The purpose of this paper is to present the MPLS network in a form of mathematical model reflecting itsservice operation of voice load. In this case, the main task of formal description of the functioning network is to be a tool that enables practically to solve the problem determining indicators of bandwidth and quality of service (QoS) on the network.

– Telecom33munications network MPLS belongs to the class of complex systems. According to the existing definition in scientific and technical literature of these systems [7,8] they have a set of properties. Main properties among them are the following:

– heterogeneity of elements, whose every element solves a particular task in the framework of a common goal of the whole system operation;
– relationships complexity between elements of the system and parameters describing them;
– complexity of solving the tasks;
– accidental character in the system processes;
– multivariate description of the system;
– the QoS dependence from many disparate of facts impact, etc.

When building a model of the MPLS network, is advisable to adhere the following principles:

1. The finiteness of the mathematical description. This principle implies that it should be processed information on the finite state variables in every point of time.
2. The hierarchy of mathematical presentation. This principle is related to partition of the studied MPLS network at several hierarchical levels with their inherent mathematical description.
3. The modularity of the mathematical description. The implementation of this principle implies completeness of the mathematical description on every level.
4. The equivalence of mathematical presentation. This method reflects the fact that each of the following on the level of description consideration of processes should result in simplifying all system properties.

Proceeding from the above, MPLS network at the first stage of formalization is advisable to provide in the form of graph $G(N,M)$, where N – nodes or switching centers, and M – branch network or bundles of channels, which they connect.

To mathematically describe the telecommunications network, you should be able to analyze aggregate branches in every way of information transmission

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$\mu_{g_{ij}}^{\nu}(i, j \in \overline{1, N})$ and ways in every direct communication $g_{ij}(i, j \in \overline{1, N})$.

The mathematical apparatus of the graph theory allows performing the procedure and optimizing the solution taking into account:

– possibilities of using weighted coefficients at the graph edges reflecting the essence of this process;

– the distribute load in ways of a minimum number of edges (branches) or transit nodes in ways of transmission information;

– possibilities to use a set of formalized algorithms, simplified simplex methods that allow determining the most effective QoS;

– the transition from graph of matrix for the network description and, for example, using the mathematical apparatus of theory of matrices to obtain the required cross-section in the network or to determine the totality of ways of information transmission in direct communication.

Bandwidth is one of the most important network characteristics. In the classic sense, bandwidth is a network ability to serve a given load volume per time unit in all communication directions to meet the requirements of service quality.

Estimation of quality of service and bandwidth of telecommunication networks

Several works present possible methods of problems solution of estimating the bandwidth telecommunication networks. We employ various assumptions to take the decision since problems of this class are quite complex. In the works [8, 9], the network is considered as a graph having the branches, which represent paths with a certain speed transmission or a given number of channels. The developed mathematical apparatus enables to determine the minimum cross-sections in directions of communication determining their limit on bandwidth. In this case, we propose to assess the channel bandwidth a total number of channels section without taking into account indicators of the service quality.

In works [6] tensor models are used to estimate the bandwidth of telecommunication networks. The branches performance in the network is described by relative weighted characteristics. The mutual influence of different directions of communication in the service process of load s is not taken into account on the branches of networks. And in real networks, each branch participates in the requests maintenance of 60% or more areas of communication. In the work [7], in general, a network of direct communications is considered and the impact of using alternative routes is not taken into account. In the work [10], we consider the process of supplying the same elements network of load of different directions of communication and use alternative routes in the process of service. However, some uncertainties arise causing errors in the calculation process. And these errors are detected only at the final stage of calculation leading to increase in time of the problem solving. In addition, new technologies (e.g. MPLS) have features that do not take into account published methods. The analysis shows that the methods of problems solving of bandwidth estimation must take into account the following factors:

1. Real operating conditions of networks, when its elements are influenced and should be taken into account when analyzing the flows of various communication areas, i.e. all threads operating in the network.
2. Requests flows that go into the service in telecommunications network have random character. This irregularity of streams applications requires the service description using the mathematical apparatus of the probability theory.
3. Regardless of the type of the net flux, the decision must be taken in the form that allows users to obtain numerical values of required indicators.
4. Mathematical model of the bandwidth evaluation should take into account the indicator of quality of the service load. If this is not the case, then this is not the indicator of bandwidth, and functioning or service load.

To solve problems of bandwidth estimation taking into account the above factors it is reasonable use the mathematical apparatus of queuing system (QS). Additionally, we should define indicators of service quality, which allow estimating the system suitability to perform its functions. QS with obvious losses is used as a model for networks serving the load real time (for example, voice load). In this case, q value, the service probability, can be the indicator of the service quality. In practice, the inverse value: $p = 1 - q$ [9] is usually used at the load service in telephone networks. It is the probability of failure in maintaining the logical channel with desired bandwidth or transmission speed. Often the value $p = 1 - q$ is referred to as simply the probability of losses probability.

Mathematical model of voice service in MPLS network

We will construct a mathematical model of voice load service in the MPLS network based on analysis of the functioning network (twelve hosts) whose structure is shown in Fig. 1.

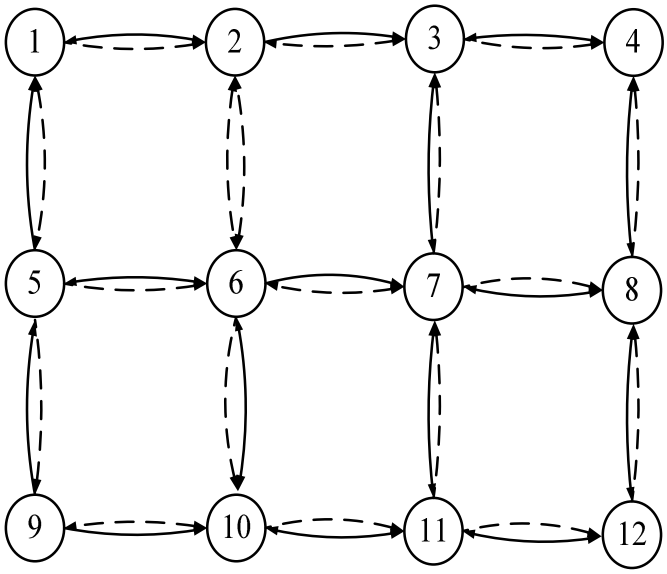

Fig. 1. The structure of MPLS network

The MPLS network is a set of nodes and branches, which are telecommunications resource. The information is transmitted the in network through communication directions. Their indicators of the quality service and bandwidth can be defined for every communication direction. Therefore, the system should be, first and foremost, obligatorily analyzed for each direction of communication. Then we should register mutual influence all areas of communication at each other. And only then you can make a conclusion on the accordance of main indicators of the network required parameters.

To reduce complexity and dimension of the problem, we propose to analyze and develop the model operation of an MPLS network in several stages. A separate problem is solved at every stage such as:

– formalizing n of the network description with the specificity of the process operation;

– decomposing the network on a set of directions connection;

– rating communication directions on a level critical to functioning parameters;

– accounting the mutual influence of lines communication in units and branches of network;

– defining the performance indicators and comparing them with regulatory parameters.

The main feature of telecommunication networks is that the values of key indicators, such as quality of service, bandwidth, reliability, are defined and regulated by lines of communication. Moreover, each line can have its own different from other normative values. Therefore, when solving problems of analysis and synthesis of telecommunication networks, it is necessary to:

1. Consider each communication direction separately.

2. Take into account the mutual influence of communication directions at each other in the process of load maintenance on the same network elements.

3. To summarize findings and draw a conclusion on conformity of required standards of indicators for the network as a whole.

The studies suggest that definition of required parameters of telecommunication networks functioning should start with communication lines with the most stringent requirements. As a rule, this is the communication direction, from which the maximum number of transits in the shortest ways of information transmission, the minimum number of detours and high demands to the service quality of incoming requests.

We perform the first stage of description formalization of network operation. To that end, we fix the relationship direction, having a maximum number of transits in the shortest ways of information transmission. We assume that it has the strictest requirements to controlled parameters. Let it be the relationship direction between the switching center 1 and 12 for this case. The branches of this communication direction are presented in the form of a set of queuing systems. Fig. 2 shows the network model.

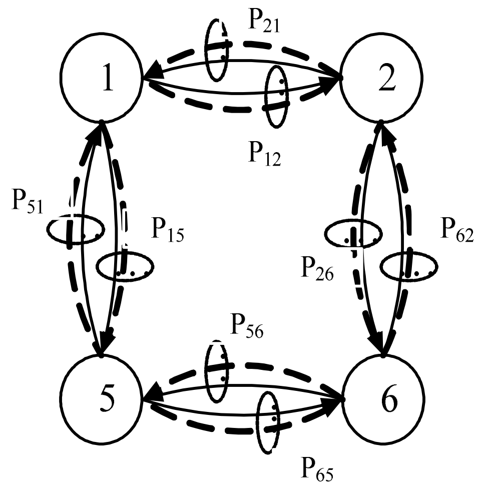

Fig. 2. The model of MPLS network

Let us consider this model behavior in terms that reflect real conditions of telecommunication networks operation.

The quality indicator $p = f(V, Z)$ [8] has nonlinear characteristics of change depending on parameters V (the number of physical or virtual channels) and Z (value of the load acting on the service) for a separate branch. For example, if the load is generated by an infinite number of sources, notably by flows in the network of the simplest ones and the network is calculated on the worst case $p = f(V, Z)$, the dependence will have the form:

$$p = \frac{\frac{Z^V}{V!}}{\sum_{i=0}^{V} \frac{Z^i}{i!}} \quad (1)$$

We will further use the mathematical apparatus for certainty. It describes the dependence $p = f(V, Z)$ of the formula type (1). In addition, change of any parameter (p, V or Z) at least of one branch network results in redistribution of the load flow, almost by 60 % of communication lines. It means that the model is very sensitive to changes of considered indicators and parameters at any network point.

The calculated expression to determine the service quality can be made for every communication direction. If there is only one only way of information transmission in the direction, the probability of losses P_{ij} in the direction of communication can be defined as follows:

$$P_{ij} = 1 - \prod_{n=1}^{k} (1 - p_n) = 1 - \prod_{n=1}^{k} \left(1 - \frac{\frac{Z_n^{V_n}}{V_n!}}{\sum_{i=0}^{V_n} \frac{Z_n^{i}}{i_n!}}\right) \quad (2)$$

where: k – a number of branches in the way of information transfer;

Z_n – load entering the service of the n-th branch in the way of information transfer;

V_n – a number of channels in the n-th branch ways of t information transmission.

If there is χ independent ways in the direction of context, the probability of losses P_{ij} (means the same as indicator of the service quality) is:

$$P_{ij} = \prod_{l=1}^{\chi} \left[1 - \prod_{n=1}^{k} \left(1 - \frac{\frac{Z_n^{V}}{V_n!}}{\sum_{i=0}^{V} \frac{Z_n^{i}}{i_n!}}\right) \right] \quad (3)$$

We perform the second stage of specification of formalized description of the network model. The request received in the direction of SC1 – SC12 network is sent in the first shortest path. In the first phase of service request, through the first node, falls on the service device, representing a multi-channel branch. If the service resource is enough in the first phase, it goes to the second service phase and passes through the second node on the branch adjacent to it. And so on. It means that the network is a multi-channel and multi-phase service system. In addition, if the resource is not enough in the selected path, then the application goes to service at the first roundabout way. If the resource at is not enough at the first roundabout way, the application goes to service at the second roundabout way, etc. If there is no required resource in any roundabout way, the request leaves the system and is not served. If the resource is enough, the request leaves the system after the service. It means that the system is open.

Thus, the Telecom network is a multi-channel, multi-phase, multiple line, open (applications removed from the system after the service, or in the absence of a resource for the service) system. Fig. 12 presents further specification of the functioning network model taking into the account a multiphase, multi-line and breach system, which allows proceeding to the model presented in figure 3.

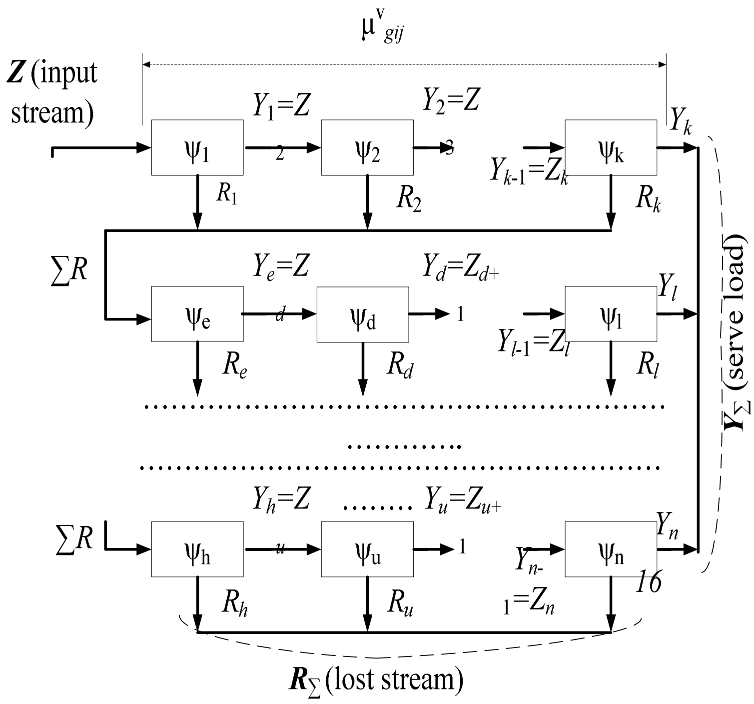

Fig. 3. Model functioning MPLS network in the direction of communication

It should be noted that each multiphase model reflects a one-way information direction of the connection direction under study for MPLS network (Fig. 4).

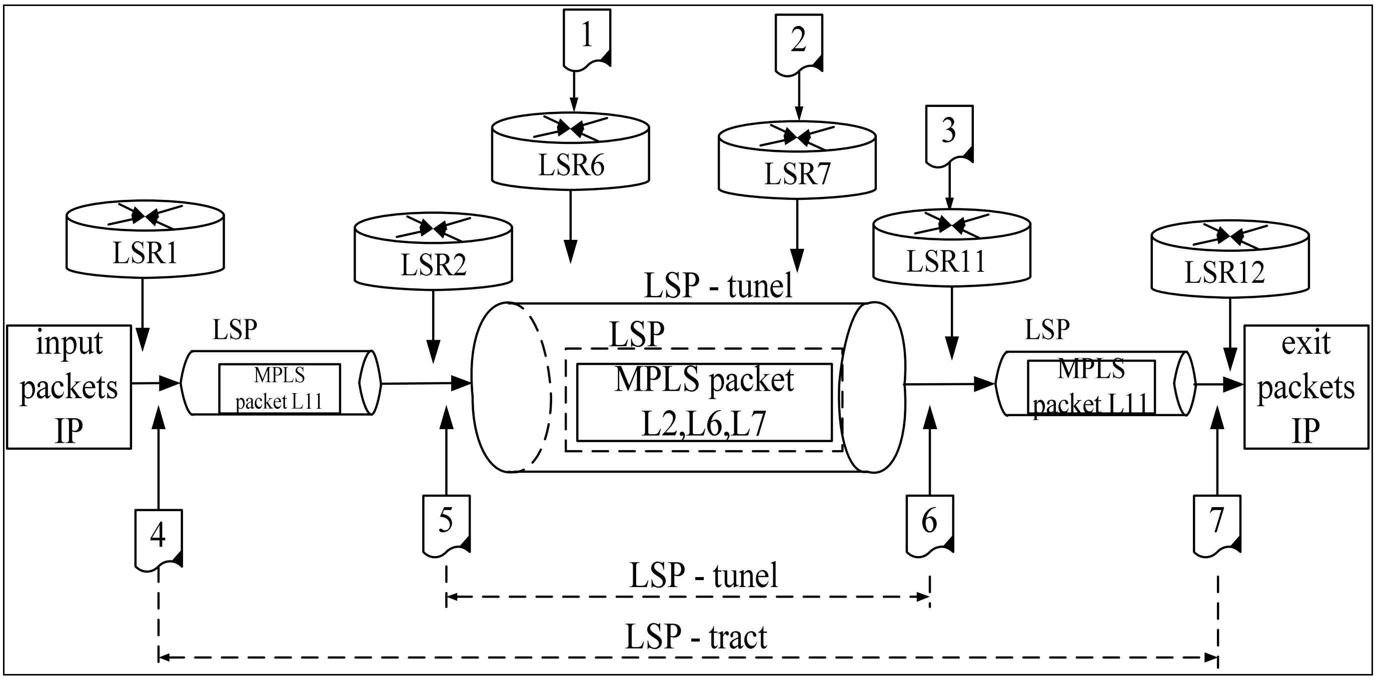

Fig 4. Tract model of MPLS network:1 – Replace label L2 to L6; 2 – Replace label L6 to L7; 3 – Replace label L7 to L11; 4 – Insert label L1; 5 – Insert label L2 (L2 – upper label); 6 – Delete label L7 (upper); 7 – Delete label L11 (last)

To increase the reliability and performance, we recommend using an independent way. The next step of the model formalization of an MPLS network requires further generalization of operation and accounting of the mutual influence of different communication directions at each other. To this end, it is necessary to specify the service processes in branches of an MPLS network.

The connection direction consists of ways of information transmission, which includes from one to κ branches. The service quality in communication directions is as a rule from the subscriber to the subscriber. Therefore, when analyzing and synthesizing telecommunication networks, it is necessary to solve the problem of translation of norms values of losses in areas of communication to the amount of allowable losses in every branch. As far as each branch of the telecommunication network may participate in maintenance of applications in a number of di communication directions, the requirements to the service quality in the network can be described by the following system of equations:

$$\begin{cases} P_{ij} = \prod\limits_{s=1}^{k_{ij}} \left[1-\prod\limits_{l=1}^{t-1}(1-p_{sl})\right], \quad i,j=\overline{1,N}; i \neq j; \\ P_{gd} = \prod\limits_{r=1}^{k_{gd}} \left[1-\prod\limits_{f=1}^{t-1}(1-p_{rf})\right], \quad g,d=\overline{1,N}; g \neq d; \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots; \\ P_{hy} = \prod\limits_{w=1}^{k_{hy}} \left[1-\prod\limits_{z=1}^{t-1}(1-p_{wz})\right], \quad h,y=\overline{1,N}; h \neq y; \end{cases} \tag{4}$$

where: $P_{ij}, P_{gh} \ldots P_{hy}$ – requirements for the valid values of normalized values of losses in the directions of communication;

$p_{sl}, p_{rf} \ldots p_{wz}$ – permissible values of losses probability in branches of the telecommunications network providing set requirements to the service quality in communication directions.

The analysis of conditions of telecommunication networks functioning, the system of equations (4) will reflect real processes only when the number of transits in all ways of information transmission is equal. To achieve equality of a number of transits in all ways of information transmission is quite difficult, so in most cases the requirements to the service quality in the network will be described as a system of inequalities in the form:

$$\begin{cases} P_{ij} \geq \prod\limits_{s=1}^{k_{ij}} \left[1-\prod\limits_{l=1}^{t-1}(1-p_{sl})\right], \quad i,j=\overline{1,N}; i \neq j; \\ P_{gd} \geq \prod\limits_{r=1}^{k_{gd}} \left[1-\prod\limits_{f=1}^{t-1}(1-p_{rf})\right], \quad g,d=\overline{1,N}; g \neq d; \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots; \\ P_{hy} \geq \prod\limits_{w=1}^{k_{hy}} \left[1-\prod\limits_{z=1}^{t-1}(1-p_{wz})\right], \quad h,y=\overline{1,N}; h \neq y; \end{cases} \tag{5}$$

The studies show the conditions of equality will be carried out only for those lines of communication, which have the most stringent requirements to the service quality.

Taking into account the fact that the first Erlang formula describes indices of the service quality $p_{sl}, p_{rf} ... p_{wz}$ in branches for the accepted system of restrictions and use of a simple flow of application in the network, a system of equations (4) takes the following form:

$$\begin{cases} P_{ij} = \prod_{s=1}^{k_{ij}} \{1 - \prod_{l=1}^{t-1} [1 - \left(\frac{Z_{sl}^{V_{sl}} / V_{sl}!}{\sum_{a=0}^{V_{sl}} Z_{sl} / a!} \right)]\}, \; i, j = \overline{1, N}; \\ P_{gd} = \prod_{r=1}^{k_{gd}} \{1 - \prod_{f=1}^{t-1} [1 - \left(\frac{Z_{rf}^{V_{rf}} / V_{rf}!}{\sum_{a=0}^{V_{rf}} Z_{rf} / a!} \right)]\}, \; g, d = \overline{1, N}; \\ \dots\dots\dots ; \\ P_{hy} = \prod_{w=1}^{k_{hy}} \{1 - \prod_{z=1}^{t-1} [1 - \left(\frac{Z_{wz}^{V_{wz}} / V_{wz}!}{\sum_{a=0}^{V_{wz}} Z_{wz} / a!} \right)]\}, \; h, y = \overline{1, N}; \end{cases} \quad (6)$$

And a system of equalities inequalities (5) takes the form (7):

$$\begin{cases} P_{ij} \geq \prod_{s=1}^{k_{ij}} \{1 - \prod_{l=1}^{t-1} [1 - \left(\frac{Z_{sl}^{V_{sl}} / V_{sl}!}{\sum_{a=0}^{V_{sl}} Z_{sl} / a!} \right)]\}, \; i, j = \overline{1, N}; \\ P_{gd} \geq \prod_{r=1}^{k_{gd}} \{1 - \prod_{f=1}^{t-1} [1 - \left(\frac{Z_{rf}^{V_{rf}} / V_{rf}!}{\sum_{a=0}^{V_{rf}} Z_{rf} / a!} \right)]\}, \; g, d = \overline{1, N}; \\ \dots\dots\dots ; \\ P_{hy} \geq \prod_{w=1}^{k_{hy}} \{1 - \prod_{z=1}^{t-1} [1 - \left(\frac{Z_{wz}^{V_{wz}} / V_{wz}!}{\sum_{a=0}^{V_{wz}} Z_{wz} / a!} \right)]\}, \; h, y = \overline{1, N}; \end{cases} \quad (7)$$

Having determined a system of equations (6) or inequality (7), you can first identify indicators of service quality in the branches of telecommunication network, and then the real value of the service quality in the communication directions. It is worthy of note that by using expressions (6) and (7) we solve the problem of analysis of the networks functioning, which is already operating. This is usually calculation of indicators of the quality of service and bandwidth lines of communication and their comparison with normative values.

Conclusion

1. The study of such complex systems as a MPLS network requires formally describing processes occurring in them, developing mathematical models describing main properties, performance of network and calculating values in required operation modes.

2. The model of MPLS network functioning is developed in the form of a multi-phase, multi-channel, the open-loop system. We show that a general conclusion on conformity of network parameters functioning to specified requirements can be made only after determining key parameters of functioning of every communication direction and evaluation of mutual influence of communication directions at each other.

3. The expression (6) and (7) allows us describing the process of mutual influence in the applications service of various directions of communication directions at the same elements of a network. By solving the system equations (6) or the system inequalities (7), we define indicators of quality of service and bandwidth channels MPLS network, compare them with norms values and determine the conformity with specified standards.

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