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ANALYSIS AND RESEARCH OF TASKS FOR OPTIMIZING FLOWS IN MULTISERVICE NETWORKS BASED ON THE PRINCIPLES OF A SYSTEMS APPROACH

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ABSTRACT

Multiservice networks support the rapid deployment of multiple applications on a single technology based on the convergence of services. When designing such a network, many complex tasks arise. When transmitting traffic in a multiservice network, developers are facing with the problem of monitoring network performance in terms of packet loss and delay. These options allow you to specify the state of the network when a user is accessing multiple applications with different needs. One of the most important problems of modern society is the creation of a telecommunications environment that will provide highly efficient access to distributed information resources. The paper proposes to investigate the qualitative indicators of a multiservice network, which characterize the most fully satisfying user requests, guided by a systematic approach. In this problem, one of the central place is occupying by the optimization of technical and economic options for building communication networks. This is especially important when it is necessary to lay the possibility of easy integration of the projected data transmission network into the existing information structure. In this regard, the article discusses the solution, based on the justification and the choice of the objective function and the development of an algorithm for optimizing flows in a modern multiservice network. The solution to the optimization problem of the distribution of flows will allow rationally distributing the existing (allocated) resources for the purpose of serving heterogeneous user flows in such a way that the loss of user requests from imperfect network functioning would be minimal. ICMP and 32-byte Ping are used as a real-time reliability-monitoring tool between two systems in a multiservice network. Also shows the use of the Packet Tracer environment for modeling the hardware-software reliability of the multiservice backbone network. The studies carried out make it possible to assess the state of equipment at the network level when transmitting information in a multiservice network, guided by a systematic approach. Therefore, these studies are of great importance and further development.

Keywords: *Multiservice network, Flows, Optimization, Objective Function, Reliability, Packet Tracer.*

1. INTRODUCTION

The functional model of a modern multiservice network has a complex distributed structure and consists of 4 levels: access level; data transport layer; network management level; service control layer.

At the level of border access, subscribers and terminals are connected to the network based on the use of various hardware and software tools and the format of the outgoing information is converted into the corresponding format used for transmission in the transport network.

At the transport level, subscribers are provided with a uniform and integrated information transfer platform with high reliability and high quality of service (QoS). At this level, Cisco 2811 series routers with an NM-4A / S expansion card and Cisco 2950-24 series switches are used, which are deployed at different points of the transport network and are interconnected using trunk communication channels with a sufficiently large bandwidth.

The main purpose of the network management layer is to provide flexible switching, which is used for call control and connection control in real time.

At the service control level, the provision of services is mainly carried out, as well as support for the functioning of the network with established connections. In the model under study, this is supported by setting up servers for different purposes.

The core of the backbone network consists of high performance routers installed at the edges of the backbone network.

Thus, a modern infocommunication network, being a complex software and hardware system, consists of both communication and switching facilities and information processing and storage facilities, as well as network resource management facilities, and performs the functions of providing various types of services and services, and also making decisions for quality service of user requests.

The main requirement for an information and communication network is the timely servicing of all types of user requests at a high quality level, within a given time frame and at the lowest cost.

The development of multiservice networks has brought many approaches to optimizing data flows to the networked world. From the point of view of the end user, it makes no difference how his information is transmitted in the transport subnetwork, or at what point in the distributed network his data is processed. He is interested in the end result - to get the information (or resource) in demand from the network in a short time, in full and at the lowest cost. Many solutions and optimization methods have been investigated, but none of them is completely effective for a multiservice network due to the characteristics of flows in the network, which have different sensitivity to time delays, and should not exceed a certain value. when transmitting data, time delays are allowed (within the normal range), Therefore, when studying the probabilistic-temporal characteristics of the network, it is necessary to take into account all types of delays. Research in this direction continues at the present time [1] - [20].

Thus, a systematic approach to the problem of optimizing the reliability of a multiservice telecommunications network involves studying the software and hardware reliability of a multiservice network, models and algorithms, that allow to study the qualitative indicators of both MSS as a whole and their individual components.

It should be noted that the analyzed works in the multiservice network is solve autonomous problems of ensuring the quality of functioning in a telecommunication network for data transmission and computer systems that perform the functions of providing computing and information resources, and others.

Solving problems of autonomous optimization, it is impossible to obtain characteristics that satisfy both the needs of users and the capabilities of the engineers, creating a multiservice network as a whole. For this purpose, the process of optimizing flows in a multiservice network based on a systematic approach is also of considerable interest.

2. GOAL SETTING

To determine the current state of research in the field of optimization in multiservice networks a review of foreign and domestic sources was carried out.

In [21], a method was developed for the comparative assessment of various alternative structures of a multiservice network, obtained as a result of the choice of one or another operator of telecommunication services; a way to ensure reliability in the event of an intentional interference in the network structure

The paper [22] is devoted to the implementation of the structural-parametric model of a telecommunication network), which provides the selection of monitoring tasks aimed at the implementation of quality control of the development of telecommunication networks. A complex of programs for managing network resources based on the models and algorithms presented in the work has been developed and implemented; a methodology for collecting and processing initial data for assessing the operational reliability and fault tolerance of an NGN network has also been developed.

In [23], the work proposed and substantiated a conceptual model of a hierarchical multiservice network using fiber-optic access technologies covering both urban and rural areas. Methods of modernization of the network infrastructure of access of urban and rural areas based on technologies of passive optical networks and hierarchical ring networks are proposed. Mathematical models of access network segments using the technology of passive optical networks based on multiphase QS are proposed and substantiated, and a numerical study of the dependences of service quality indicators on various parameters of traffic service processes with three classes of relative priorities in different phases of service, in the downstream and upstream directions, taking into account network access mechanisms. Based on these models, an analysis of the quality of service characteristics was carried out, taking into account the influence of the topological structure, using the example of the network core, for three traffic classes: IP telephony (VoIP), IP television (IPTV), computer data.

In [24], a complex of mathematical models was developed for calculating and assessing the functional reliability of a transport network, taking into account the peculiarities of its complex topology and the development of hardware support for information technologies, substantiated and implemented technical solutions aimed at increasing the reliability of the vehicle control system, based on the use of existing natural and additional resources in the form of software and hardware. The novelty of this work can be considered the establishment of links and dependencies between the structure parameters of a multiservice system and its reliability, which made it possible to develop methods and models for assessing its functional reliability, in accordance with the decisions made on the transport network management system.

The papers [25]-[26] presents a methodology for developing a model of a backbone multiservice IP / MPLS network for studying traffic behavior, its throughput, latency and other characteristics of various classes, developing a network model architecture, studying the parameters of network equipment, routing technology when using various routes.

In [27], a methodology for developing a model of a backbone multiservice IP MPLS network for studying traffic behavior, its bandwidth and other characteristics of various classes based on IP PBX Asterisk is presented. The analysis is based on the method of calculating the Pearson criterion.

In [28] considers network design and optimization of high-speed multiservice networks. We investigate the problem of optimizing the division of bands for high-speed multiservice networks. The optimization model is designed to divide the bandwidth between the bands to minimize the total cost of the system in conditions of bandwidth constraints, while guaranteeing QoS at the call level. For this purpose, the system uses the concept of effective bandwidth. To meet the requirement of frequent strip separation, a fast algorithm based on simulated annealing is presented to solve the model. The results of modeling are presented, demonstrating the effectiveness of the approach to optimization.

The publication [29] presents a multipurpose routing model for multiprotocol label switching networks with several types of services and traffic sharing. The routing problem is formulated in the form of a multicriteria mixed integer program, in which the objectives under consideration are to minimize the cost of routing, bandwidth and minimize the cost of loading network channels with a restriction on the maximum separation of traffic backbones. To solve this problem, two different exact methods have been developed: one is based on the classical method of constraints, and the other is based on a modified method of constraints.

In [30], the paper presents a multipurpose routing model for multiprotocol label-switched networks with several types of services and path protection. The routing problem is formulated as a bio-objective integer program, in which the objectives under consideration are formulated in accordance with the approach to network-wide optimization, that is, the objective functions of the route optimization problem clearly depend on all traffic flows in the network. For each traffic trunk, a pair of disjoint paths is considered to ensure that the corresponding connection is protected. An exact method for solving the problem has been developed.

The publication [31] notes a large number of smart attacks and malicious intrusions. As a basic measure of network security, network data collection monitors the network in real time, supports network performance assessments, assists with network billing, and helps test and filter traffic. Thus, it plays a critical and important role in detecting network intrusions and managing unwanted traffic. It is noted that an adaptive and efficient data collection mechanism that could be widely used in heterogeneous networks is still lacking.

A properly designed and constructed transport network ensures high operational reliability of the network and ultimately reduces operating costs. It should be noted that with the development of multiservice networks, the share of operating costs in comparison with the initial capital costs increases and therefore the analysis and targeted planning and implementation of measures to improve the reliability of the components of a multiservice network during their operation should be given great attention.

Two aspects characterize the reliability of a multiservice network: the reliable functioning of its constituent parts and the ability of the network to continue functioning in the event of failure of its individual sections.

To implement these aspects, it is necessary to take into account the properties of the internal parameters of the multi-service network backbone. These include the speed and transmission protocols in communication channels, as well as the reliability

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characteristics of the channels (equipment performance, algorithms for the functioning of flexible switches and their reliability characteristics), determined by the specific structure of the multiservice network. Based on this, to study the hardware reliability of a multiservice network on the backbone, the routing protocol EIGRP was configured and Cisco equipment was selected.

Investigating software reliability, it is necessary to take into account the properties of the program to perform the specified functions, to maintain its characteristics within the established limits under certain operating conditions. Software reliability is determined by its reliability and recoverability. To check the mechanism of the failure, the Ping value was changed to the delay in the line when transmitting information in a multiservice network and the ICMP protocol, in which reliability parameters lead to a denial of service. The denial of service is due to the discrepancy between the software of the equipment used for the tasks set.

Research in the field of network reliability is now widespread. With the transition to multiservice networks, the issue of ensuring reliability at all levels of the multiservice network architecture remains a challenge. Reliability is one of the most important factors affecting QoS, since a multiservice network must provide high-quality transmission of heterogeneous traffic, including traffic sensitive to delays. When failures and failures appear in network channels and technical means, the normal operation of all users in the network is disrupted, which leads to large losses for companies providing various types of services. Therefore, the closest attention is paid to the study of the reliability indicators of the transport layer of a multiservice network, the processes occurring in the network are studied, bottlenecks in their implementation are discovered, and the reliability of the network is monitored and the quality of information exchange in the transport sub network is determined.

A lot of modern studies by foreign and other authors are devoted to the analysis and assessment of the reliability of information systems and telecommunication network structures. For example, in [32], a study of the reliability of signal transmission in a multiservice network was carried out with the determination of a set of parameters. The studies carried out prove the dependence of reliability on the technical characteristics of the equipment.

Most studies in the field of network reliability, such as [33]-[34], [39], consider only random failures and describe denial of service nodes. In the article [40], the authors propose to investigate a wireless network on reliability under the influence of several parameters simultaneously, which include not only denial of service of nodes, but also the influence of power consumption, environmental randomness and interference. Reliability parameters are also relevant in the study of a modern multiservice network using blockchain functions.

In [35], a multiservice business model based on blockchain technology was investigated, which simultaneously processes service flows according to different quantitative indicators and in different ways ensures the reliability and quality of service.

Paper [36] presents a scenario for using IoT technology to control subsea network devices over the Internet using the new Water Ping protocol based on ICMP protocol technology, which allows subsea devices to successfully send and receive ping messages.

The article [37] examines the role and advantages of the applied software package of the batch tracer in mastering the technology of building computer networks. The ability to explore computer networks without realizing the real network is very important.

In [38], a method of building a network using the Packet Tracer program based on the routing protocol EIGRP is investigated.

Based on the analysis of the above publications, we conclude that the transport system of a multiservice network is a fundamental component of a large information system with a distributed structure, and its reliable functioning fully determines the increase in the efficiency of a large system. In other words, the effectiveness of a multiservice network with a distributed structure, as a complex system, is associated with the reliability of the transport system and its individual components.

3. RESEARCH METHODOLOGY OF TASKS FOR OPTIMIZING FLOWS IN MULTISERVICE NETWORKS BASED ON THE PRINCIPLES OF A SYSTEMS APPROACH

The study of the qualitative indexes of a multiservice network, which will fully satisfy the needs of users, is proposed to be carried out on the basis of a systematic approach.

It is known that delays can occur during the transmission of user messages over the transport subnetwork and during the processing of its requests in processing systems. Therefore, when studying the probabilistic-temporal characteristics of a network,

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it is necessary to take into account both types of delay: either at the transport level or at the data link level, or at the level of service presentation in processing systems.

From the point of view of the end user, it does not matter how his information is transmitted in the transport subnetwork, or at what point in the distributed network his data is processed. He is interested in the final result - to receive information from the network in a short time, in full and at the lowest cost [25] - [26].

In the general case, the time spent by the user in the network is determined by the total delay arising in the processing and transmission of its fragments (packets) in all parts of the network:

$$T_{\Sigma} = T_{AL} + T_{TL} + T_{CL} + T_{SL} \quad (1)$$

where TAL is the delay at the access level, TTL is the delay at the transport level, TCL is the delay at the switching control level, and TSL is the delay at the service level.

Thus, the time spent by users in the components of the multiservice network can be functionally divided into two components:

- the time required for the transmission of the request through the transport network to the required resource of multiservice network{ti};

- the time required to service a request in information processing systems of the multiservice network MSN {tj}.

Then the total time spent by the user in the network will be equal to the sum of two components:

$$\{t\} = \{t_i\} + \{t_j\} \quad (2)$$

The delay at each level has a complex distribution, since at each moment of time, depending on the state of the external traffic parameters and the components of the considered level, the time spent by the request at this level is random. It is necessary to minimize the time for the entire period of traffic passing through all components of the multiservice network. For this, it is proposed to take into account the temporal characteristics of both the transport subnetwork and in the processing systems of the multiservice network as a general parameter. This approach will allow a systematic approach to the distribution of existing resources for the purpose of serving heterogeneous user flows and reduce the loss of user requests from imperfect network functioning.

The task of managing the distribution of heterogeneous traffic both between the components of the transport network and between the components of the level of service provision of a multiservice network is one of the key ones, which make it possible to ensure the required level of quality of service in the network by distributing limited, geographically dispersed network resources.

In this regard, the purpose of this paper was to develop an algorithm for distributing traffic flows, taking into account the load of the transport subnet and service delivery systems, based on a systematic approach, taking into account the characteristics of the selected objective function.

The main indicators that characterize the efficiency of a multiservice network are performance, response time and cost. The performance of the multiservice network determines the number of served user requests for a given time interval N (0, t).

The residence time of the user's request is defined as the duration of the time interval from the moment the user's request arrives in the multiservice network until the moment it ends.

In the general case, this indicator is a random value and characterizes the time spent by the request in the multiservice network - treq. It consists of two terms: runtime and latency.

The task execution time is equal to the total duration of all stages of the process of transferring and processing a request: input, transfer, processing and output –tserv.

The waiting time is the sum of the time intervals during which the request was in the waiting state for the required resources - tw.

$$t_{req} = t_w + t_{serv} \quad (3)$$

The cost is the rent for servicing the user's request, which is a function of the time the request remains in the components of the multiservice network:

$$\{C_i\} = F[\{t_{req}\}] \quad (4)$$

The functioning of a multiservice network can be represented in the form of processes that implement the main functions specified by the corresponding programs, determined based on user assignments, received by the multiservice network from the external environment. Such events include the moments of the start of the process, the beginning and end of processing of individual requests, the beginning and end of the execution of processes in the processing systems of the multiservice network, the beginning of the use and release of resources provided to the process in the components of the multiservice network, etc. processor time and memory.

If we take the performance of the multiservice network (or the rental cost) as the objective function, then the optimization problem of constructing the multiservice network can be formulated as follows: it is necessary to select the components of the multiservice network in such a way as to maximize its performance when choosing certain options for servicing user requests while fulfilling the specified restrictions.

The adoption of such a decision is explained by the fact that in many cases it is required to satisfy user requests in conditions of limited resources, that is, it is necessary to store more data in the allocated space, process the request faster without consuming a lot of energy and not allocating too large resources, transfer more information over the available communication channels, to ensure the maximum degree of readiness of the operated computer and other systems. And all this must be ensured in conditions of limited funding.

In such conditions, competent design of the multiservice network is a key link to achieve its effective operation, and the specified limitations determine the choice of technologies, equipment and software used.

In information technology, the situation is rapidly changing, more and more powerful computer systems and memory equipment appear on the market, which leads to a constant increase in the cost of resources. In such a situation, a real problem arises - how, in conditions of a constant increase in the cost of resources, to get the most out of the operation of existing equipment, that is, it is necessary to find ways and methods to satisfy user demands in conditions of limited resources.

In other words, it is necessary to find an answer to the question - how, given the possible degree of load growth, recovery processes after failures and high availability to important applications and services, to increase the main indicators (performance, reliability, etc.) of the multiservice network.

In the absence of a unified approach and appropriate standards for the distribution of limited resources of the multiservice network dictates the need to solve this problem from a systemic standpoint, that is, to solve the problem of allocating resources between the requests of the multiservice network users by developing models and methods for providing network, computational, information and other services to a wide range of users, based on methods of system analysis.

2.1 Justification and Choice of the Objective Function

It should be noted that the performance of the multiservice network is determined by the average residence time of a user's request in the system. The more efficient the multiservice network and the optimally distributed flows of external traffic between its components, the less time it will take to execute requests and vice versa.

Summarizing the above and taking into account expression (2), we can assume that the total residence time of all incoming requests in the components of a multiservice network in general form is a function of two variables.

$$T = F[T_1, T_2], \qquad (5)$$

T1 is the total residence time of all incoming user requests served without the involvement of the multiservice network processing systems.

$$T_1 = \sum_{i=1}^{N_1} T_1^i , \qquad (6)$$

T2 total residence time of all incoming user requests served with the involvement of the multiservice network processing systems.

$$T_2 = \sum_{j=1}^{N_2} T_2^j, \qquad (7)$$

N1, N2 - the number of user requests served without and with the involvement of the multiservice network processing systems

The total residence time of requests of all types will be equal to:

$$T = T1 + T2 = \sum_{i=1}^{N_1} T_1^i + \sum_{j=1}^{N_2} T_2^j \qquad (8)$$

It is proposed to use this expression as an optimality criterion when solving the problem of optimal distribution of heterogeneous flows in the multiservice network.

The expediency of choosing this expression as an objective function is explained by the fact that the less time for servicing a request, the more requests can be serviced in a given period and increase the profit obtained through the operation of the multiservice network.

Guided by this approach, the optimization problem can be formulated as follows: it is necessary to distribute the flows of external traffic of the multiservice network in such a way that the total time spent by all types of user requests in the components of the multiservice network would be minimal while ensuring the stationarity of the functioning of the multiservice network components, that is

$$\left[\sum_{i=1}^{N_1} T_1^i + \sum_{j=1}^{N_2} T_2^j\right] \to min \quad (9)$$

In this formulation of the problem, it is required to distribute flows between the means of information transmission and processing in such a way that the total average time of servicing all user requests under the same conditions would be minimal if the given constraints are met.

2.2 The Flow Distribution Algorithm

The task of the flow distribution algorithm in the network is to determine for each branch of flows such a virtual path, the transmission of data along which is carried out with minimal time delays.

The optimization model is based on graph theory as well as a queuing system. According to this theory, the characteristics of the total input traffic in a multiservice network is determined by the following expression:

$$\gamma = \gamma_1 + \gamma_2, \quad (10)$$

γ1 - total traffic from sources to destinations without using information or computing resources of the network (transit traffic);

γ2 - total traffic from sources to destinations using information or computing resources of the network (information and computing traffic).

In turn, γ2 can be interpreted as the sum of two traffic:

$$\gamma_2 = \gamma_2^{ex} + \gamma_3, \quad (11)$$

γ_2^{ex} - total external traffic;

γ3 - total internal data traffic.

Let us represent the structure of the basic model of a given multiservice network in the form of a graph G {M, A}(where M is a nonempty set of vertices and A is a set of edges such that a∈A finite number of ordered pairs of elements (i, j), (i , j∈M), which determine the beginning and end of the edge), each edge (i, j) corresponds to the probability distribution function of the transmission time of the number of arrivals along the channel (edge) Fi, j (t).

Input flows are described by the distribution function of the moments of arrival to the network, to node i for node j - φi, j (t). Input and output streams are assigned to nodes associated with consumers.

The routing procedure in the model is determined by a matrix of routing variables:

$$\Psi = \| \varphi_{i,j}^{(k)}(t) \|, \quad (12)$$

$\varphi_{i,j}^{(k)}(t)$ - the probability of sending a message (packet) at node i at time t, addressed to node k along the edge (i, j), k = 1, 2,. ... ... M, (i, j) ∈A.

It's obvious that

$$\sum_{j \in M} \varphi_{i,j}(t) = 1, \quad (13)$$

$$\varphi_{i,j}^{(k)}(t) \geq 1 \quad (14)$$

The rate of the total flow through node i to node j is determined from the expression:

$$\varepsilon_{i,j} = \gamma_{i,j} + \sum_{k \epsilon M} X_{k,i}^{(j)}. \quad (15)$$

The rate of the flow through along the edge (i, j) from all k-nodes is:

$$X_{i,j} = \sum_{k \epsilon M} X_{i,j}^{(k)}. \quad (16)$$

Flow and route variables are related by the following expression:

$$\begin{cases} X_{i,j} = \sum \varphi_{i,j}^{(k)} \varepsilon_{i,j}, k \epsilon M \\ \varphi_{i,j} = \frac{X_{i,j}^{(k)}}{\varepsilon_{i,k}}, \varepsilon_{i,k} > 0 \end{cases} \quad (17)$$

These expressions for the flows Xi,j represent a system of linear equations with known input flows. Its solution will make it possible to determine the routing table of the transport multiservice subnetwork (the routing table of node i is a collection of all routes along which information can be delivered to node i for a given set $\{\varphi_{i,j}^{(k)}\}$.

The task solved within the framework of the described flow model allows one to determine the values of the routing variables and the rates of the corresponding flows, minimizing the function of the total average time of message delivery:

$$\min T = \sum_{(i,j) \epsilon A} T_{i,j}(X_{i,j}). \quad (18)$$

The optimization model proposed in this paper takes into account both types of delays simultaneously, characterizing the distribution of "information" and "transit" traffic flows over the communication channels of the transport subnetwork and processing systems of computer systems.

According to the optimization model, the flow distribution algorithm consists of principle of system approach and the following steps:

1. Input of initial data (number of nodes, channels, values of channel capacities, rate of flows, gravity matrix of flows between nodes, etc.).

2. Calculates of shortest paths in the metric of channel capacities $\{C_i\}^{(h)}$, h=0.

3. Determination of the shortest paths with the minimum number of channels with the maximum bandwidth.

4. Direction of the list of external traffic flows γ_2 along the shortest path channels.

5. Determination of new shortest paths taking into account the congestion of channels and computer systems.

6. Transfer of certain directions of flows from the old path to the new path or to another computer system, taking into account their congestion with external traffic data flows.

7. Performs the functions of transferring a list of flows to active nodes, processing flows on computer systems and transferring processed information to addressees.

8. Calculates the final value of the objective function and stops the algorithm.

4. SIMULATION AND RECEARSH OF A MULTISERVICE NETWORK

Guided by this principle of system approach, the structure of the multiservice network system model can be represented as a basic set of functional components that contain:

1. Server complex, which includes:

- servers of computing and information resources (resource servers);
- application servers;
- servers providing computing and information resources provide an interface between users and application servers.

2. Data storage complex - external data storage devices that provide reliable storage of information resources and provide access to them.

3. The data transmission network complex includes routing and switching equipment, communication channel devices, user terminals, as well as information security means.

4. A software package that provides centralized management of all components of a multiservice network and monitoring their status in real time.

A multiservice network is a multidimensional network in which a transport network, a synchronization network, a signaling and access network, as well as service networks are integrated for joint reliable, high-quality and safe provision of various services to consumers.

The tasks of managing and distributing information flows are one of the key ones that allow solving problems of blocking and overloading in the transport network, choosing a route and transit centers, etc., that is, they are actually aimed at the rational distribution of limited, geographically dispersed resources of a multiservice network.

The solution to the flow control problem is mainly reduced to the distribution of geographically dispersed resources in the transport sub network of the multiservice network. The development is based on the principles of a systematic approach and the selected objective function.

The developed model of the multiservice network consists of the following devices:

1) Cisco 2811 series routers with NM-4A/S expansion board;
2) Switches 2950-24 series;
3) PCs;
4) FTP, DHCP, HTTP servers;
5) IP phones.

According to the proposed the flow distribution algorithm, the arhitecture of the network consist of 10 nodes and 36 channels has been illustrated in Figure 1, the main nodes were configured, the IP addresses were allocated, the EIGRP routing protocol was configured. The bandwidth of the communication channels was specified as the distribution of the message delivery time with the average value.

The advantages of the EIGRP Protocol include:

- High-speed technology for functioning in large networks.
- Significantly less channel loading and memory usage when the protocol is running.
- The ability to balance traffic over non-equivalent channels.

The disadvantage of the EIGRP protocol is that it is limited to the number of nodes equal to 100 and is closed, that is, it can be implemented only on Cisco Systems equipment.

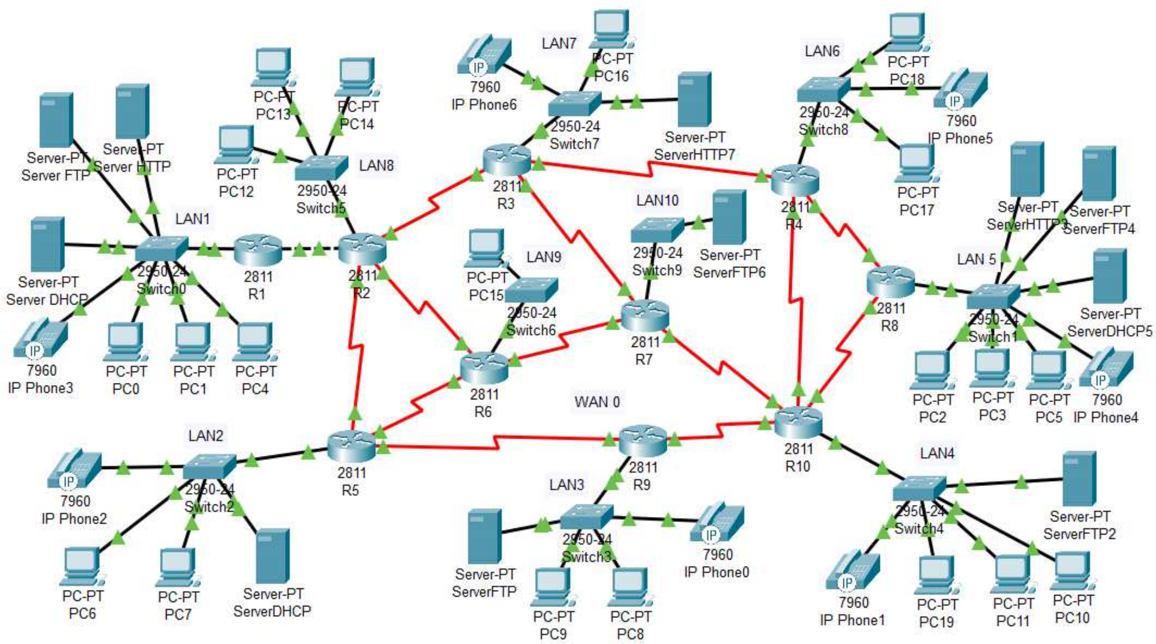

Figure 1: Network architecture before optimization.

To test the availability of nodes, a 32-bit Ping from PC4 from LAN 1 with the address 192.168.1.8 to PC2 in LAN 5 with the address 192.168.15.5 was established, which is shown in Figure 2. Using the Ping command, we tested the passage of packets from PC4 with the address 192.168.1.8 to the backbone network to router R2 with the address 192.168.15.5. connection established.

The first result means that the device being accessed is responding (if a DNS address is used, ping will translate it to its equivalent IP address). This demonstrates that you are connected to the Internet and that the corresponding remote device is working.

```
PC>ping 192.168.15.5

Pinging 192.168.15.5 with 32 bytes of data:

Reply from 192.168.15.5: bytes=32 time=25ms TTL=123
Reply from 192.168.15.5: bytes=32 time=12ms TTL=123
Reply from 192.168.15.5: bytes=32 time=12ms TTL=123
Reply from 192.168.15.5: bytes=32 time=12ms TTL=123

Ping statistics for 192.168.15.5:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 12ms, Maximum = 25ms, Average = 15ms
```

Figure 2: Ping Passes Result

The second result shows that the number of packets sent (Sent) - 4, delivered (Received) - 4, lost (Lost) - 0. The loss of transmitted Ethernet packets is "0%".

The third result is the average round trip time of the packet in milliseconds. The average round trip time of a packet is 15 ms. This is the best possible result of the command. It indicates a low network load and no need to send the same information again.

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5. RESULTS OF SIMULATION OF A MULTISERVICE NETWORK

On the basis of the algorithm, a program was compiled and tested when entering the initial data of the considered network topology [27].

The functions of the algorithm are performed in three stages. At the first step, options for constructing the shortest paths between the communication nodes of the network of a given topology are determined.

At each iteration, a specific variant of constructing the shortest tree for a specific node is selected and the entire flow is directed along these paths, according to the gravity matrix (table 1).

Table 1 shows the results of an experiment on the distribution of the shortest paths between nodes 1 and 10. 100 realizations were carried out. In each case, the value of the message delivery time was determined according to the given distribution, that is, the "edge cost" was determined and the program for finding the shortest paths was launched. The table summarizes the numbers of nodes along which the shortest path between 1 and 10 passes, the number of nodes along the path and the probability of choosing this path.

Table 1: Shortest path search result

No. of path	No. of nods on the network	Number of nods	Probability
1	1-2-3-4-8-10	6	0.3618
2	1-2-6-7-10	5	0.152
3	1-2-5-9-10	5	0.345
4	1-2-3-7-10	5	0.066
5	1-2-3-4-10	5	0.0642

The shortest paths with a probability less than 0,005 are excluded from consideration and are not shown in the table. Thus, if it is required to determine 5 different shortest paths between nodes 1 and 10, then they will be the first five options. The options for the shortest paths between all other nodes in the network are determined in a similar way.

At the step 2, on the basis of the calculated shortest paths, the problem of optimal distribution of "computational" traffic between the computer systems of active nodes is solved. Statistical modeling of the processes of transmission of message packets to virtual channels of the transport subnetwork and processing of messages in computer systems of active nodes is carried out, and the value of the objective function is calculated from the results of the simulation.

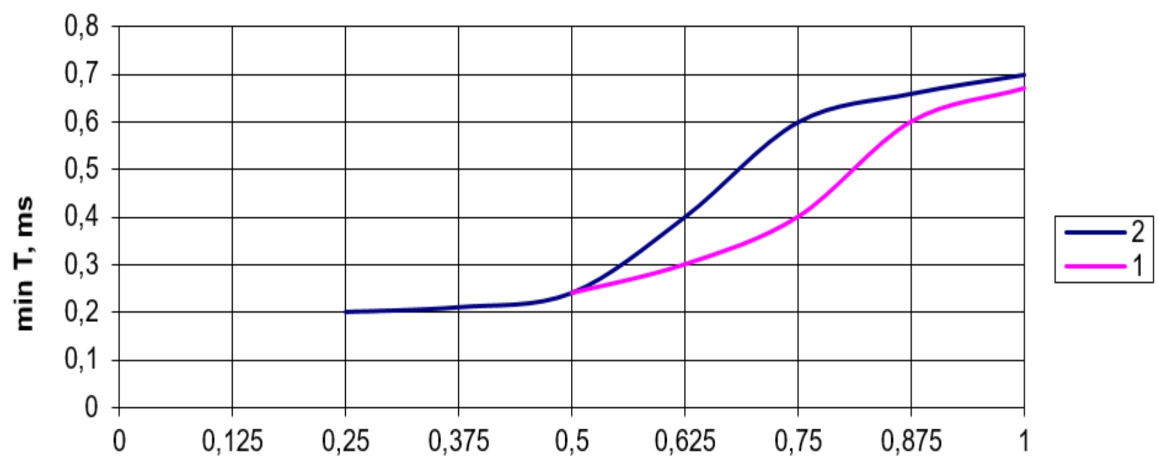

Figure 3: Dependence Of The Minimum Total Average Data Delay Time During The Formation Of The Transport Subnetwork Before Optimization (Line 2) And After Optimization (Line 1)

Figure 3 is presented dependence of the minimum total average data delay time during the formation of the transport sub network before and after optimization. At the third stage, the optimization of flows and paths is carried out according to the flow distribution algorithm. After determining the optimization network topology, the distribution of different types of flows in the multiservice network is performed. Minimizing the values of the objective function, we come to the solution of hardware reliability of multiservice networks is becoming more and more urgent, since equipment failure can lead to disasters.

The proposed approach can be applied in a number of industries to improve the profitability of using networks.

Hardware reliability contains a number of aspects related to network design and analysis and depends on random failures of network elements. The hardware reliability of a multiservice network is determined by the reliability of its constituent elements. Calculations of hardware reliability must be made at the technical design stage, when the composition of the network, its structure and principles of operation are already known in more detail, allowing you to check the correctness of the design decisions, find "weak points" and develop certain recommendations to improve the reliability and efficiency of its functioning.

To date, there are insufficiently studied methods for assessing the reliability of devices that are critical to the delay in computation results. This manifests itself in the inadmissibility of waiting for requests in the queue and in the impossibility of resuming the computational process after a failure occurs. Solving such problems is relevant for multiservice networks. Cisco routers are considered in our work as a device that can fail when servicing requests, either in a free state, or in either state.

Let's take the probability of all routers to work as 1, and the probability of each router is calculated based on the ratio of the total number of routers in the multiservice network to the total probability. Let us assume that the probability of operation of an individual element is equal to 0.1.

A study of hardware reliability was carried out when path were removed one by one from the architecture of the multiservice backbone network. When path between R6 and R7 is removed, the average delay is 14 ms. Figure 4 shows the result of node availability.

```
Ping statistics for 192.168.15.5:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 13ms, Maximum = 19ms, Average = 14ms
```

Figure 4: Ping Passes Result

When path between R2 and R6 is removed, the average delay is 12 ms. Figure 5 shows the result of node availability.

When path between R7 and R10 is removed, the average delay is 12 ms. Figure 6 shows the result of node availability.

```
Ping statistics for 192.168.15.5:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 12ms, Maximum = 13ms, Average = 12ms
```

Figure 5: Ping Passes Result

```
Ping statistics for 192.168.15.5:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 7ms, Maximum = 14ms, Average = 11ms
```

Figure 6: Ping Passes Result

As a result of removing 3 paths, ping passes to the designated node in 11 ms, which confirms the reliability of the network under study. For this reason, we can conclude that incremental path removal keeps the network stable by using nodes of the same parent to forward traffic to the sink, avoiding continuous logical topology changes that can cause failures. While the transmission delay remains within the norm. Figure 7 shows the network after removing the routers.

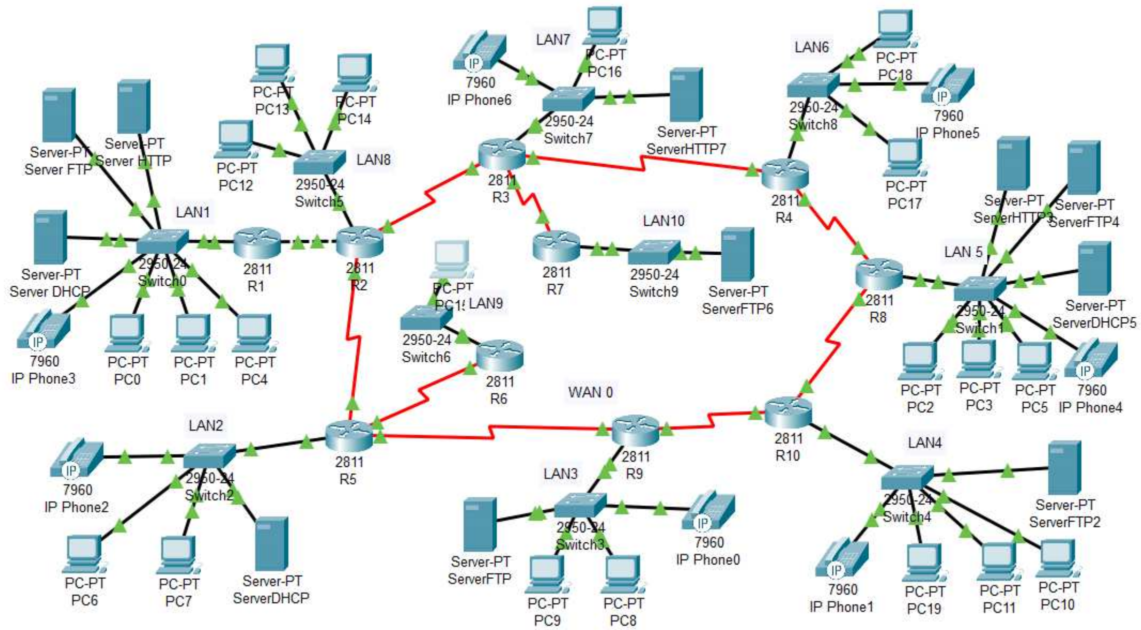

Figure 7: Network Architecture After Optimization

Of the fact, one of the most effective and fairly easy to implement methods for increasing the hardware reliability of multiservice networks is redundancy / duplication or redundancy. However, during redundancy, the task arises to ensure the specified reliability indicators, to achieve economically profitable indicators with the lowest total costs for redundant elements, or, with the given resource constraints, to achieve the maximum possible hardware reliability of the entire network.

For this, one of the most important characteristics of reliability is usually singled out, for example, "cost", but in practice, situations are more common when restrictions are imposed on several resources.

The issues of reservation of the investigated multiservice network are planned to be considered in future works.

5.1 Research of Software Implementation of the Reliability of the Backbone Part of a Multiservice Network

Ping command sends Internet Control Message Protocol (ICMP) Echo-Requests to the specified host and records the received responses (ICMP Echo-Reply). The time between sending a request and receiving a response (RTT, from the English Round Trip Time) allows you to determine two-way delays (RTT) along the route and the frequency of packet loss, that is, indirectly determine the congestion of data transmission channels and intermediate devices.

Ping is also called the time spent on transferring a packet of information in computer networks from client to server and back from server to client, it is measured in milliseconds. Ping time is related to the speed of the connection and the load of the channels all the way from the client to the server.

To research the software reliability of the backbone part of a multiservice network, an experiment was carried out when the value of pings changed upward during their transmission over the network with an interval of 1 ms, as shown in Table 2.

Table 2: Delay Dependence From Ping Value

Ping value, bit	Delay, ms
32	17
1024	17
2048	19
4096	21
8192	27
10000	29
12000	31
14000	33
14500	35
15000	-

Table 2 shows that when the ping value is higher than 15000 bits, the echo requests disappear and there is a denial of service for the equipment.

When pinging to other devices on a multiservice network, receiving complete no ICMP replies may mean that the remote host (or any of the intermediate routers) is blocking the ICMP echo reply or ignoring the ICMP echo request.

The ping program is one of the main diagnostic tools for TCP/IP networks and is included in all modern network operating systems. The ping functionality is also implemented in some of the embedded operating systems of modern routers.

6. CONCLUSIONS

Simultaneous servicing of multiple user requests in a multiservice network with a given topological structure is a complex multi-stage task.

To solve this complex problem, the article proposes to consider the infrastructure of modern multiservice networks as a functionally connected complex of hardware and software tools for processing and exchanging information, consisting of geographically distributed information processing subsystems, switching nodes and physical information transmission channels, which was previously considered separately.

The widespread use of the ICMP protocol is known, but its modeling and study in a multiservice backbone network in combination with the EIGRP routing protocol in the Packet Tracer environment was made for the first time with a change in the delay values.

These studies have shown that when using ICMP vulnerabilities as the basis for creating an attack on the network to disrupt network equipment, the degree of equipment denial of service increases with increasing overhead costs. The value at which a total denial of service occurs is greater than 15,000 bps.

The results of a study of hardware reliability of a multiservice backbone network show that the network operates reliably with 50% equipment availability and has an average delay of 11 ms.

To solve the problem of flow control in a multiservice network, an optimization model for the distribution of application flows in a multiservice network has been developed. An optimization model for the distribution of flows between limited resources of a multiservice network is based on graph theory and queuing systems. The model development is based on the principles used in routing and flow control problems, as well as the system approach.

The flow distribution problem, solved according to the proposed model, is formulated in the following form: to minimize the convex function that takes into account both types of delays simultaneously, characterizing the distribution of "information" and "transit" traffic flows over the communication channels of the transport network while fulfilling the linear constraints necessary to ensure the stationarity of the flows online.

A software implementation of the proposed algorithm for the distribution of heterogeneous flows in multiservice networks has been developed, which is aimed at ensuring efficient data transportation between end users, preventing errors in data transmission, blocking and congestion in the communication network, choosing a route and transit nodes, etc., that is, directed on the rational distribution of limited, geographically dispersed network resources that ensure the transmission and processing of user requests.

REFERENCES:

[1] V. Romanchuk, A. Polishuk, M. Beshley, M. Seliuchenko. Method for Processing Multiservice Traffic in Network Node Based on Adaptive Management of Buffer Resource. 14th International Conference on Advanced Trends in Radioelectronics, Telecommunication s and Computer Engineering (TCSET), 2018, pp. 1118-1122. DOI: 10.1109/TCSET.2018.8336390.

[2] V. Kartashevskiy, M. Buranova. Analysis of Packet Jitter in Multiservice Network. 2018 International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S&T 2018), pp. 797-802. DOI: 10.1109/INFOCOMMST.2018.8632085.

[3] A. Rassaki. Managing QoS in Multiservice Data Networks. Proceedings of The World Congress on Engineering and Computer Science (WCECS), 2017, Vol. 1, pp. 74-79. http://hdl.handle.net/10210/248030.

[4] A. Rassaki, A. Nel. Optimizing Capacity Assignment in Multiservice MPLS Networks. South African Computer Journal, Vol. 29, No.1, June 2017, pp. 69-89. DOI:10.18489/sacj.v29i1.393.

[5] A. Rassaki and A.L. Nel. Optimal Capacity Assignment in IP Networks. International Conference on Digital Information Processing and Communications (ICDIPC 2015), Oct. 2015, pp. 256-261. DOI: 10.1109/ICDIPC.2015.7323038.

[6] Y.A. Pignole, S. Schmid, G. Tredan. On the Implications of Routing Models on Network Optimization. IEEE Transactions on Network and Service Management (IEEE TNSM), vol. 18, no. 4, pp. 4756-4769, Dec.2021.

DOI:10.1109/TNSM.2021.3090312.

[7] Z. Dulinski, G. Rzym, P. Cholda. MPLS-based reduction of flow table entries in SDN switches supporting multipath transmission. Computer Communications, vol. 151, pp. 365-385, Feb. 2020. DOI:10.1016/j.comcom.2019.12.052.

[8] K.S. Amorim, G.S. Pavani. Ant Colony Optimization-based distributed multilayer routing and restoration in IP/MPLS over optical networks. Computer Networks, vol.185, Feb. 2021, Art.no. 107747. DOI:10.1016/j.comnet.2020.107747.

[9] I. Kalesnikau, M. Pioro, M. Poss, D. Nace, A. Tomaszewski. A Robust Optimization Model for affine/quadratic flow thinning: A traffic protection mechanism for networks with variable link capacity. Networks, Vol. 75, No. 4, Jun 2020, pp. 420-437. DOI:10.1002/net.21929.

[10] S.Z. Xu, X. Wang, G.X. Yang, J. Ren, S. Wang. Routing Optimization for Cloud Services in SDN-based Internet of Things with TCAM capacity constraint. Journal of Communications and Networks, Vol. 22, No. 2, pp. 145-158, Apr. 2020. DOI:10.1109/JCN.2020.000006.

[11] M. Chiesa, A. Kamisinski, J. Rak, G. Retvari, S. Schmid. A Survey of Fast-Recovery Mechanisms in Packet-Switched Networks. IEEE Communications Surveys and Tutorials,Vol. 23, No. 2, 2021, pp. 1253-1301. DOI:10.1109/COMST.2021.3063980.

[12] A. Roy, J.L. Pachuau, A.K. Saha. An Overview of Queuing Delay and Various Delay based Algorithms in Networks. Computing, Vol. 103, No. 10, Oct. 2021, pp. 2361-2399. DOI:10.1007/s00607-021-00973-3.

[13] N. Geng, Y.Yang, M.W. Xu. Flow-level and Efficient Traffic Engineering in Conventional Routing System. Computer Networks, Vol. 185, Feb. 2021, Art.no. 107671. DOI:10.1016/j.comnet.2020.107671.

[14] A. Sharma, P. Cholda, R. Kumar, G. Dhiman. Risk-aware Optimized Quickest Path Computing Technique for Critical Routing Services. Computers & Electrical Engineering, vol. 95, Oct. 2021, Art.vo. 107436. DOI:10.1016/j.compeleceng.2021.107436.

[15] A.M. Sllame. QoS of Communication Networks using MPLS Protocol. Intelligent Wireless Communications, IET Telecommunication Series, Vol. 94, 2021, pp. 177-220. DOI: 10.1049/PBTE094E_ch.

[16] M.Z.Yakubova, T.G.Serikov, A.D.Mekhtiev, A.D.Alkina, Y.G.Neshina. Development and imitating modeling in the developed network consisting of several knots removed among themselves on NetCracker 4.1. IEEE 2016 Dynamics of Systems, Mechanisms and Machines (Dynamics), Omsk, Russia, 2017, doi:10.1109/Dynamics.2016.7819108.

[17] T.G. Serikov, A. Zhetpisbayeva, A. Akhmediyarova, Sh. Mirzakulova, A. Kismanova, A. Tologenova, W. Wójcik. City backbone network traffic forecasting. International Journal of Electronics and Telecommunications, 2021, vol. 67(3), pp. 319–324, doi: 10.24425/ijet.2021.135983.

[18] O.A. Manankova, B.M. Yakubov, T.G. Serikov, M.Z. Yakubova, A.K. Mukasheva. Analysis and research of the security of a wireless telecommunications network based on the IP PBX Asterisk in an Opnet environment. Journal of Theoretical and Applied Information Technology, Vol.99, No.14, 2021, pp. 3617-3630.

[19] M.Z. Yakubova, T.G. Serikov. Development and imitating modeling in the developed network consisting of several knots removed among themselves on NetCracker 4.1. International Conference of Young Specialists on Micro/Nanotechnologies and Electron Devices, EDM, Art.no 7538726, 2016-August, pp. 210–213, DOI: 10.1109/EDM.2016.7538726.

[20] T.Z. Teshabayev, M.Z. Yakubova, T.N. Nishanbayev, M. Amreev, G.S. Sadikova. The formation of the structure of a multiservice network based on communication equipment from different manufacturers. International Conference on Information Science and Communications Technologies: Applications, Trends and Opportunities, ICISCT 2019, doi: 10.1109/ICISCT47635.2019.9011830

[21] L. S. Vygovsky. Method, methodology and ways to ensure the reliability of integrated computer networks. Ph.D. dissertation, Saint Petersburg Electrotechnical University "LETI", Saint Petersburg, Russia, 2011.

[22] A.E. Perfiliev. Models and algorithms for calculating the operational reliability and fault tolerance of telecommunication systems. Ph.D. dissertation, HSE Moscow Institute of Electronics and Mathematics, Moscow, Russia, 2012.

[23] I.E. Nikulsky. Models and methods for constructing broadband optical access networks. Ph.D. dissertation, Central Research Institute of Communications, Saint Petersburg, Russia, 2011.

[24] A.E. Marchenkov. System analysis and management of a multiservice system based on functional reliability methods. Ph.D.

dissertation, Research Institute of Computing Complexes M.A. Kartseva, Moscow, Russia, 2012.

[25] S.V. Konshin, M.Z.Yakubova, T.N. Nishanbayev , O.A. Manankova. Research and development of an IP network model based on PBX asterisk on the opnet modeler simulation package. International Conference on Information Science and Communications Technologies (ICISCT 2020), Article no. 20486746, doi: 10.1109/ICISCT50599.2020.9351405.

[26] T.Z. Teshabaev, M.Z. Yakubova, O.A. Manankova. Analysis, research and simulation of a multiservice network based on the Packet Tracer software package to determine the value of delays to increasing value size of ICMP packet. International Conference on Information Science and Communications Technologies (ICISCT 2020), Article no. 20486756, doi: 10.1109/ICISCT50599.2020.9351479.

[27] M.Z.Yakubova, O.A. Manankova, K.A. Tashev, G.S. Sadikova. Methodology of the determining for Pearson's criterion based on researching the value of delays in the transmitting of information over a multiservice network. International Conference on Information Science and Communications Technologies (ICISCT 2020), Article no. 20486776. doi: 10.1109/ICISCT50599.2020.9351419.

[28] V. K. Sharma. Reliability evaluation and optimal design in heterogeneous multi-state series-parallel systems. Information Sciences: an International Journal, Vol. 181, No. 2, Jan. 2011, pp. 362- 378. DOI: 10.1016/j.ins.2010.09.015.

[29] R. Girao-Silva, M. F. Jose, J. Climaco, M. E. Captivo. Multiobjective routing in multiservice MPLS networks with traffic splitting - a network flow approach. Journal of Systems Science and Systems Engineering, Vol. 24, No. 4, Jan.2015, pp. 389–432, doi:10.1007/s11518-015-5262-4.

[30] R. Girao-Silva, J. Craveirinha, T.Gomes, L. Martins, J.Climaco, J. Campos. A network-wide exact optimization approach for multiobjective routing with path protection in multiservice multiprotocol label switching networks. Engineering Optimization, Vol.49, No. 7, 2017, pp. 1226-1246. DOI: 10.1080/0305215X.2016.1235706.

[31] D. Zhou, Zh.Yan, Y. Fu, Zh.Ya. A survey on network data collection. Journal of Network and Computer Applications, Vol. 116, Aug. 2018, pp. 9-23. DOI: 10.1016/j.jnca.2018.05.004.

[32] Amreyev M., Yakubov B., Safin R., Yakubova M. Improving the Quality and Reliability of Signal Transmission and Reception in Multiservice Networks». News of Thenational Academy of Sciences of the Republic of Kazakhstan. Physico–mathematical series. ISSN 1991-346X. Vol.2, No 330 (2020), pp. 75 – 79. doi.org/10.32014/2020.2518-1726.17.

[33] Glabowski M., Kmiecik D., Stasiak M. Overflows in Multiservice Systems. IEICE Transactions on Communications. E102B (5), 2019, pp.958-969. DOI: 10.1587/transcom.2018EUI0002

[34] Kurt, S., Yildiz, H. U., Yigit, M., Tavli, B., & Gungor, V. C. (2017). Packet Size Optimization in Wireless Sensor Networks for Smart Grid Applications. IEEE Transactions on Industrial Electronics, 64(3), 2392–2401. DOI:10.1109/tie.2016.2619319

[35] Leal F., Chis A. E., González-Vélez H. Multi-service model for blockchain networks. Information Processing & Management, Vol.58, No.3, 102525. Doi:10.1016/j.ipm.2021.102525

[36] Lima, F. H. M. B., Vieira, L. F. M., Vieira, M. A. M., Vieira, A. B., & Nacif, J. A. M. (2019). Water Ping: ICMP for the Internet of Underwater Things. Computer Networks. DOI:10.1016/j.comnet.2019.01.009

[37] Sheikh Raashid Javid. Role of Packet Tracer in learning Computer Networks. International Journal of Advanced Research in Computer and Communication Engineering. Vol. 3, No. 5, May 2014, pp. 6508-6511.

[38] Srikanth Reddy P., Saleem Akram P., Adarsh Sharma M., Aditya Sai Ram P., Pruthvi Raj R. Study and Analysis of Routing Protocols. International Journal of Emerging Trends in Engineering Research. Vol 7, No 11. 2019, pp. 434-440.

[39] Xiang S., Yang J. Reliability Evaluation and Reliability-Based Optimal Design for Wireless Sensor Networks. IEEE Systems Journal. - pp.1-12. Doi:10.1109/jsyst.2019.2932806

[40] Zhang, X., Lyu, C., Shi, Z., Li, D., Xiong, N. N., & Chi, C. (2019). Reliable Multiservice Delivery in Fog-enabled VANETs: Integrated Misbehavior Detection and Tolerance. IEEE Access, doi:10.1109/access.2019.2928365