Results of simulation modeling of technical parameters of a multiservice network

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ABSTRACT

In a scientific article, the authors presented the results of simulation modeling of the technical parameters of a multiservice network. As a model of a multiservice communication network for the computational experiment, the model proposed in the previous scientific publications of the author was chosen. The selected model uses the Laplase-Stilles transform. Simulation modeling was carried out using the technical parameters of the multiservice network's availability factor and network load. Scientific results of experimental research work are given in the form of tables. Relations of the probability of betime servicing of an application on the load of a multiservice communication network for various availability factors and the probability of untimely service of an application on the availability factor for numerous network loadings are obtained. The character of the distribution of costs necessary for the implementation of solutions for different categories of technical operation is shown. Scientific research on determining the objective function's minimum value is presented in graphs and diagrams. The results of simulation modeling of the technical parameters of multiservice networks are presented in the form of diagrams using the Matlab software environment.

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1. INTRODUCTION

The author's scientific articles present the developed model of a multiservice communication network. This developed model allows you to analyze the technical parameters of a multiservice communication network from the point of view of a systematic approach. In this model, network components are presented as several separate subsystems, which are independent levels. Levels perform certain functions in batch mode with a given quality of service. The authors substantiate the expediency of determining the technical parameters of an info-communication network based on a systematic approach, taking into account the reliability of each network level. The scientific novelty of this work lies in the fact that using the previous works of the author, it is proposed to solve the problem of studying the technical parameters of multiservice communication networks using system analysis and using the Matlab software environment [1]-[3].

In Muradova [4], a model is proposed that allows, from a systemic point of view, to investigate the reliability indicators of an info-communication network (ICN) with a distributed structure, the essence of which is to represent the components of the ICN as subsystems that are independent levels and perform specific functions in batch mode with a given quality of service. The paper substantiates the expediency of determining the reliability indicators of ICN based on a systematic approach, taking into account the reliability states of each network level. In this paper, it is proposed to rationally distribute the resource allocated to ensure the reliability of the studied ICS between the network levels. In other words, it is proposed to minimize the resource allocated to ensure the required reliability of the ICN, taking into account the company's cost losses arising from the residual unreliability of the network components. When executing user requests, as a rule, all elements of the ICN take part, and the unreliable functioning of at least one element can negate all the work performed by other network components. The appearance of failures and failures in network channels and gateways, in routing and switching centers, in information processing and storage systems, as well as in network resource management systems lead to a disruption in the normal operation of both operators and all users (clients), which leads to large losses of companies providing various types of services [5], [6].

Five characteristic features can be identified for ICN networks. The first feature is the use of packet technologies in the transport network to transfer all kinds of information. The second feature is the use of distributed architecture switching systems that differ from traditional (functionally oriented) telephone exchanges. The third feature is the separation of service support functions from switching and transmission. The fourth feature is the provision of broadband access for any user. The fifth feature is the implementation of operational management functions (including those delegated to users) using web technologies.

The functional model of ICN networks is represented by 4 levels: 1) access level, 2) transport layer, 3) network management layer, and 4) service management level. At the level of border access, subscribers and terminals are connected to the network based on the use of various means and the format of outgoing information is converted into the appropriate format used for transmission in this network. The transport layer handles packet switching and transport, and uses devices such as routers and layer 3 internet protocol (IP) switch distributed in the backbone network and transport network (MAN) [7], [8]. This layer provides subscribers with a uniform and integral transmission platform with high reliability, high quality of service (QoS), and large bandwidth. The network management layer controls calls. The underlying technology at this layer is flexible switching, which is used for real-time call control and call setup control. Softswitch is the main device that implements the functions of the switching and information transfer control level. At the service control level, the provision of additional services is mainly carried out, as well as support for the operation of established connections. The next generation network, being a complex technical system, can in a particular case be an information network that provides various types of services to users. This system includes both communication facilities and an information processing and management system that performs the functions of the required network maintenance and decision making for quality user service [9].

Network fault management: you can have a designated network fault management team to anticipate, detect, and resolve network faults to minimize downtime. In addition to fault resolution, this function is responsible for logging fault information, maintaining records, conducting analysis, and aiding in regular audits. There need to be clear channels so that the network fault management team can report back to the network administrator to maintain transparency. It will also work closely with the end-user in case they report faults. Network configuration management: network configurations are a key aspect of performance. These configurations are expected to change dynamically to keep up with data and traffic demands in a large enterprise. Network configuration management relies heavily on automation so that the team does not need to manually look up configuration requirements and can provision changes automatically instead. Like network fault management, the network configuration management team must also keep detailed records of all changes, their outcomes, and issues, if any. Network accounting and utilization management: as network requirements evolve, employees will consume more network resources and add to enterprise costs. The network accounting management team monitors utilization finds anomalies and tracks utilization trends for different departments, business functions, office locations, online products, or even individual users. Network performance management: this is one of the most central aspects of network management. Network performance management involves various tasks that help boost network uptime, service availability, and concurrent bandwidth speeds. Here too, automation plays a major role. A singular dashboard is connected to various network components that monitor performance key performance indicators (KPI) and raises an alert if a threshold is breached. Network security management: as most enterprise processes move online, network security is vital for resilience, risk management, and success. In a distributed denial-of-service attack (DDoS), multiple connected online devices target an enterprise website with fake traffic to block legitimate traffic. Network security management involves protecting a system against these and other issues. An enterprise network also generates a regular stream of logs analyzed by the network security management team to find any threat fingerprints [10].

2. RESEARCH METHOD

Let’s find the optimal value of the objective function proposed in the scientific work of Lin and Yeh [11]. It is necessary to present the investigated multiservice network as a queuing model according to the international Kendall classification of the type $M_i / I_j \ / \ R_{\infty n} \ / \ d_{1n}$. Here M_i is the rate of incoming requests to the multiservice network, which is expressed by the law of exponential distribution. I_j – the system operates in real reliability mode. $R_{\infty n}$ is the service method with n-wait indefinite time. d_{1n} is the direct order of servicing n-requests in the systems. Conventionally, the queuing systems (QS) is divided into two parts: the part in which needs arise is called the served system (population, part of production), and the part that accepts requirements and satisfies them is called the service system (transport, post office, shops). The queuing systems include: 1) a source, 2) an incoming flow of requests, 3) a queue, 4) a server, and 5) an outgoing flow of serviced requests. Now it is necessary to calculate the logical-probabilistic technical parameters of the developed model (Figure 1).

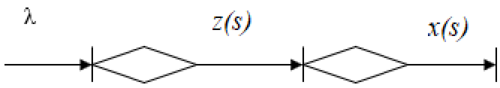


Figure 1. Request servicing model in a multiservice network for research the main parameters

In accordance with the developed model, two basic incidental processes take place in these research systems: the expectation process, which is described by an incidental time t_z. As well as the service process, which is characterized by a random time t_{cb}. According to Kendall’s laws, due to additivity, we calculate the service time of a random request t_s:

$$t_s = t_z + t_{cb} \tag{1}$$

The possibility of betimes delivery of applications for this model is defined as:

$$Q_b = z(s) \cdot x(s), Res \geq 0 \tag{2}$$

Where $z(s)$ is the integrated Laplase-Stilles transform of the distribution function of the waiting time for requests; $x(s)$ is the integrated Laplase-Stilles transformation of the distribution function of the service time of applications; $Re(s \geq 0)$ is a constraint according to which the relation of (2) is satisfied only under the condition $s \geq 0$.

Taking into account that in this system the processes of failure and recovery of serviced messages occur, we define the expression for $x(s)$ using this expression:

$$x(s) = \frac{\mu(s+d)}{(s+d)(s+\mu)+cs} \tag{3}$$

And the expression for $z(s)$ will have the form:

$$z(s) = \frac{(1-\lambda s_1)s[1+\frac{c}{d+c}]k_g}{s-\lambda+\lambda x(s)} \tag{4}$$

Here $s_1 = 1/\mu k_g$.
Given the known parameters $x(s)$, $z(s)$, the expression for Q_b will look like this:

$$Q_b = z(s) \cdot x(s) = \frac{\mu k_g - \lambda}{\mu k_g - \lambda + s[1+\frac{\mu k_g k_p}{s k_g + d}]} \tag{5}$$

Using basic mathematical notation, the final mathematical formula for the possibility of timeous servicing of requests from subscribers and users will look like this:

$$Q_b = (\mu_E - \lambda) \ / \ (\mu_E - \lambda + s_E) \tag{6}$$

$$\begin{cases} s > 0, \mu_E \geq \lambda, \mu_E = \mu k_g \\ s_E = s[1 + \mu_E k_{pi}/(s k_g, + d_i)], \mu = C_{\sum}/V_i, k_{pi} = 1 - k_g \end{cases}$$

Where: k_{pi} is the equipment lay-up coefficient in the multiservice network, k_g is the network availability factor. C_{Σ} is the capacity of this network. V_i is the mean percentage of number of i-requests. λ is arrival rate and traffic frequency, average number of requests per queue as overall arrival rate increases. μ is the frequency of receipt of requests for servicing applications in the network. c_i is the intensity of correct operation of the equipment. d_i is the speed of reduction of devices after a failure and s is the rate of obsolescence of requests, under the condition that the law of allocation of all accidental variables is exponential [12].

3. THE DECISION OF THE PROBLEM

The research of the influence of the availability factor of a multiservice network on the technical parameters of this network was made on the basis of the developed model. Applying (2)-(5) for calculations [13]. This experiment was carried out at different values of the coefficient of readiness K_g and load ρ_i of the multiservice network. Here, the value of the frequency of receipt of applications for their service remains unchanged. The results of this experimental research on the developed model given in Table 1.

Table 1. Results of experimental research on the developed model

Availability factor k_g		The possibility of timeous servicing of incoming requests in a multiservice network				
λ	ρ_i	0.81	0.9	0.95	0.99	0.999
0	0	0.808	0.909	0.952	0.983	0.99
10	0.1	0.7875	0.898	0.946	0.981	0.989
30	0.3	0.725	0.869	0.931	0.976	0.986
50	0.52	0.612	0.816	0.904	0.967	0.980
70	0.7	0.346	0.689	0.84	0.946	0.968
80	0.81	0	0.526	0.759	0.92	0.953

Analysis of the table showing that in the failure of a network load on a multiservice network, a change in the coefficient of readiness from 0.81 to 0.999 leads to an improvement in the probability of timely circulation of applications – from 0.808 to 0.99. With an average network load (within, $\rho_i \approx 0.52$) from 0.612 to 0.98. At relatively high network loads ($\rho_i \approx 0.81$) - from 0.81 to 0.953 parameters. The following figure shows another exchange in the possibility of betimes communication services of applications from subscribers when observed in cases of different values of the intensity of the ingoing flow of applications for fixed values of K_g (Figure 2). Figure 3 shows the dependence of the probability of untimely calls for service on the availability factor for different network parameters load [14].

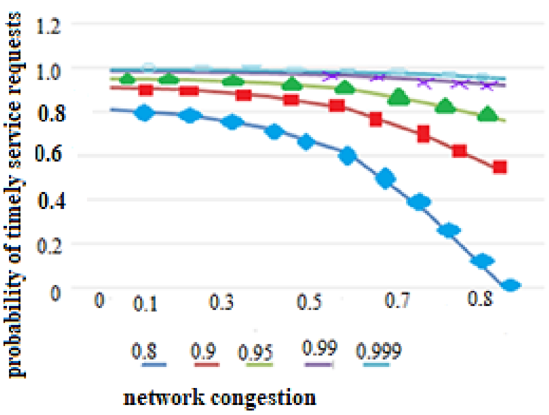


Figure 2. Graph of the dependence of the probability of timely delivery of requests on the load of the multiservice network for various meanings of K_g

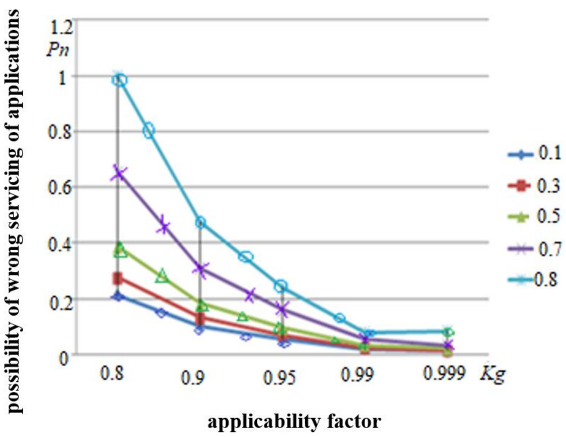


Figure 3. Graph of the relation of the possibility of wrong servicing of applications on the values of the applicability factor K_g for different loads of the multiservice network

These obtained results according to the developed model are the basis for determining the value of the goal function in system analysis. Let us determine the statistical values of a multiservice network that characterize the reliability parameter of the components and equipment of each level. We calculate the values of the availability factor parameter K_g^i for each level and the multiservice network as a whole (Table 2).

Fulfillment of user requests to a certain extent depends on the reliable functioning of network components and equipment at each level of the network and on the degree of its load. If we take into account the flow parameters of the queuing system (QS) model [15] (Figure 1), we determine different assessments of the probability of betimes service of applications and the probability of untimely service of applications that arise due to poor quality and untimely service of subscribers and users.

In the Table 2, the designations are accepted: C: $G-1\ /\ K_t-1$ – communication channel from the gateway of the access level to the switch of the transport level. $CS_n -$ a communication server that n-provides a secure connection of service level servers to an external network (that is, to the multiservice network control level equipment). R-router (service level router); S-service level servers; T_0, T_V, K_g, T_0^M, T_V^M, K_g^M - are the values of the average uptime of the equipment for a certain period of time, the average downtime, the equipment availability factor before and after the implementation of measures to improve reliability [16]-[20].

Table 2. Estimations of the parameters of the coefficient of readiness K_g^i of the equipment of each level of the multiservice network

No		Name of equipment	T_0	T_V	K_g	T_0^M	T_V^M	K_g^M
Access level equipment	1	Gateway - first	8759	3.1	0.99966	8759	3.1	0.99966
	2	Gateway - second	8550	4	0.99953	8551	3	0.99964
	3	Gateway - third	9021	2.6	0.99971	9021	2.6	0.99971
	4	Switch - first	8756	4	0.99954	8756	4	0.99954
	5	Switch - second	8934	3	0.99966	8934	3	0.99966
	6	Switch - third	8455	5	0.99941	8457	3	0.99964
	7	C: $G -$ first / K_t - first	8455	5	0.99941	8457	3	0.99964
	8	$G-2$ / router - third	8453	3.3	0.9996	8458	2	0.99976
	9	$G-3$ / router - second	9021	5	0.99945	9025	2	0.99978
	10	K_d - first / K_t- first	8756	4	0.99954	8756	4	0.99954
	11	K_d - second / router - third	8934	3	0.99966	8934	3	0.99966
	12	K_d - third / K_t - second	8453	4	0.99942	8456	4	0.99963
	13	T_{d2} / K_t - First	8456	6	0.99940	8456	2	0.99968
	14	T_{d3} / router - third	8758	3	0.99965	8758	3	0.99965
Transport equipment	15	Switch – first (K_t - first)	8753	6	0.999427	8756	4	0.99965
	16	Switch – second (K_t - second)	8932	5	0.99944	8933	4	0.99955
	17	Switch – third (K_t - third)	8456	4	0.99953	8458	2	0.99976
	18	Router - first	8756	5	0.999429	8757	4	0.99954
	19	Router - second	8452	3	0.99943	8453	5	0.99964
	20	Router - third	9019	4.6	0.9996	9020	3.4	0.99962
	21	C: K_t - first / router - first	8756	5	0.999429	8757	4	0.99954
	22	Router- first / router- third	9016	3.2	0.99964	9017	1.5	0.99983
	23	K_t - first / router - second	8453	3.3	0.9996	8458	2	0.99976
	24	K_t - second / router - third	8933	4	0.99955	8935	2	0.99978
	25	K_t - third / router - second	8454	3.4	0.9997	8459	2.3	0.99977
	26	Router- first / softswitch	9018	3.5	0.9996	9019	3.5	0.99961
	27	Router- second / softswitch	9016	3.2	0.99964	9017	1.5	0.99983
	28	Router- third /softswitch	9012	2.3	0.99970	9013	0.4	0.99995
	29	K_t - second /softswitch	9025	3	0.99980	9032	4	0.99965
Soft-switch	30	Softswitch	8753	1	0.9999	8756	7	0.999313
	31	Softswitch/CS_n	8543	1.9	0.99985	8545	9	0.99884
Service level equipment	32	Server - first (S_1)	9015	0.5	0.99994	9016	6	0.999334
	33	Server – second (S_2)	8750	0.3	0.99996	8755	5	0.999429
	34	Server – third (S_3)	8930	0.1	0.999989	8932	5	0.99944
	35	Server – fourth (S_4)	8454	0.2	0.999976	8456	4	0.999527
	36	CS_n	8755	0.12	0.999989	8760	8	0.99898
	37	Router	9023	1.0	0.9999	9029	5	0.99945
	38	C: R / KS	9012	4	0.99966	9013	9	0.99910
	39	Router / $server_1$	8752	2.5	0.9997	8756	4	0.99954
	40	Router / $server_2$	8931	3	0.99967	8932	5	0.99944
	41	Router / $server_3$	8456	4	0.99953	8458	2	0.99976
	42	Router / $server_4$	8754	2.2	0.99976	8758	9	0.99887

4. RESULTS AND DISCUSSION

Based on the obtained results, the dependence of the probability estimate of untimely service of the request P_{un} and the frequency of receipt and λ of received requests in the multiservice network determines the estimate of cost losses, that is:

$$C_{NT} = f(P_{un}, \lambda) \tag{7}$$

The estimate of P_{un} depends on the coefficient of readiness, i.e., $P_{un} = f(k_g)$, and the amount of cost reduction is a function of the coefficient of readiness $C_p = F[f(k_g), \lambda)]$. Suppose that in a multiservice network with different network load intensity, there are three streams of requests (voice, video streams and data), then the losses from non-fulfillment of requests will be of three types, summing them up, we determine the sum of the total losses. In the next step, we determine the amount of costs required to increase the cost of K_g. Let's use the method described in the second part of this scientific work. To make a specific decision on technical operation, certain costs are required. Their significance varies depending on the category of user requests. Maintenance engineers know that relatively little investment is required when making preventive maintenance decisions. And localization of equipment and restoration are quite expensive. On Figure 4 shows a graph of cost growth for another category adopted for the computational experiment. The first two categories of technical operation solutions are used when the value of the availability factor parameter is normal, and losses occur due to untimely requests for servicing requests and due to uneven distribution of the network load in the network [21]-[23].

The allocated funds for the network spent on the execution of distribution and redistribution operations. As a result of the operations of the named classes of technical operation – due to the transfer of flows from the overloaded part of the network to unloaded sections – the average time of request execution is reduced. This leads to a decrease in the probability of request loss, and hence to a decrease in cost losses (Figure 5(a) and Figure 5(b)) [24], [25]. If the value of K_g is below the norm, the allocated funds for the network are distributed according to C_Z between solutions of 3 and 4 classes of technical operation. In the first step, we calculate the total amount of costs and expenses. Which are allocated for the implementation of the main solutions of the "localization" class. Next, we calculate the technical parameter K_g.

If the mathematical expression is met:

$$K_g \geq K_{gdop} \tag{8}$$

Then P_{NT}, $C_{NT,}$ and, $C_{\sum} = C_{ZT} + C_{NT}$ calculated.

If the mathematical expression is not met, the next option for distributing costs for this category of technical operation is selected and condition (2) is checked. Going through the options, the option determined in which C has a minimum value. If (8) is not met, the value of the distributed amount of network costs increases, that is, a gradual transition to the fourth category of decisions is made, and so on until (8) is met. When determining the desired variant, the values of the parameters P_{NT}, C_{NT} and $C_{\sum} = C_{ZT} + C_{NT}$ calculated. The equipment of the control and service levels is made of highly reliable elements, and therefore the parameters of their reliability, as a rule, are in the normal range.

Models of access levels, transport and service presentation based on the presented resource by the control system modernize their structure and calculate the reliability parameters of the elements. Based on the generated version of the multiservice network (MSN) structure, the process of servicing user requests is modeled and the network parameters characterizing the quality of service are calculated and the company's losses are determined that have arisen due to residual unreliability during its operation based on the considered version of the network structure. The value of the objective function is calculated and compared with the value obtained in the previous version. If the value has decreased, the results of this variant are saved, the results of the previous variant are discarded.

$$\{C_{ZT}\}_i = b_{(d)} \times \{C_{ZT}\}_i + b_{(t)} \times \{C_Z\}_i + b_{(u)} \times \{C_{ZT}\}_i + b_{(us)} \{C_{ZT}\}_i \tag{9}$$

The coefficients $b_{(u)}$ and $b_{(us)}$ are equal to zero and will be written as:

$$\{C_{ZT}\}_i = b_{(d)} \times \{C_{ZT}\}_i + b_{(t)} \times \{C_{ZT}\}_i \tag{10}$$

If the options for forming the network structure are finite, all options are considered and the option that provides the minimum value of the objective function is selected. In the case of considering an ICN with a complex structure, which contains many options (for example, more than a thousand), the search for a minimum is carried out based on the use of heuristic methods for searching for an extremum. Figure 5(b) shows the results of a scientific study. When the network reliability requirement condition is not met. On the graph, along the y-axis, the values of the number of funds and costs aimed at improving the reliability of the C_{ZT} ICN network are plotted. The sum of losses and costs resulting from the unreliable operation of individual components of the C_{NT} ICN network. Also the $sum\Sigma C_{\sum} = C_{ZT} + C_{NT}$. On the abscissa options for the distribution of funds and costs for improving reliability. As can be seen from the curves, on the 1st graph in the 3rd variant, on the 2nd graph - in the 4th variant, the objective function extremum is reached.

The following figures show the result of a scientific experiment to determine the minimum score of the objective function. Which ensures the fulfillment of the requirements for the reliability of a multiservice communication network, using the Matlab software environment. Figure 6 shows the result of the simulation modeling of all devices of the subscriber access level of the ICN. Figure 7 demonstrates the simulation results of modeling transports layer equipment, specifically routers and, switches of the 3-d layer. Figure 8 represents the simulation results of the control plane hardware, specifically the Softswitch hardware. Figure 9 shows the simulation results of the service level equipment, namely the equipment of various servers.

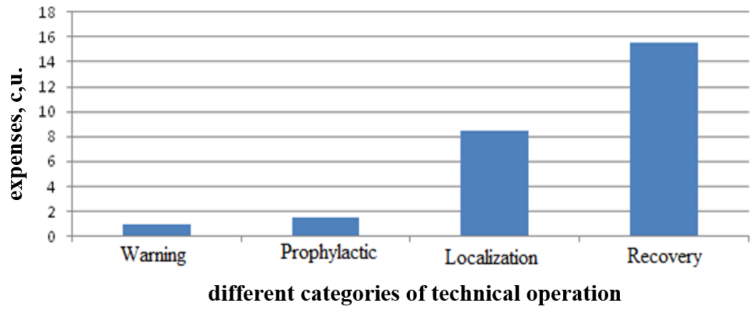
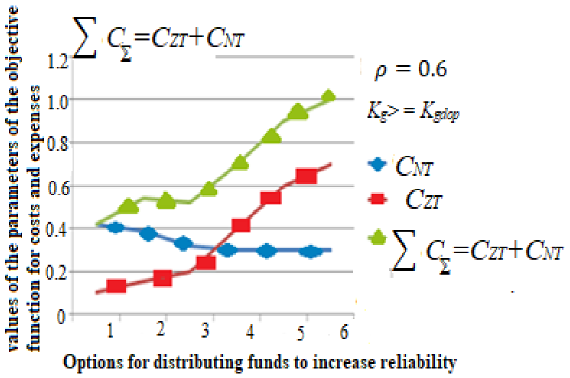
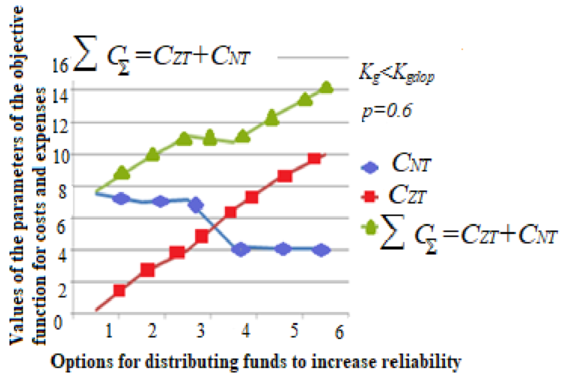


Figure 4. Distribution diagram of network costs required to implement solutions for different categories of technical operation



(a)



(b)

Figure 5. The results of the computational experiment of determining values of the parameters of the objective function for costs and expenses, under the condition: (a) $K_g >= K_{gdop}$, and (b) under the condition $K_g < K_{gdop}$

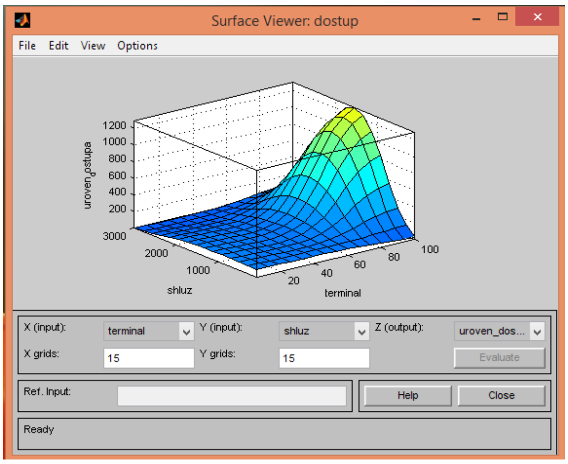


Figure 6. Results of simulation modeling of access layer equipment

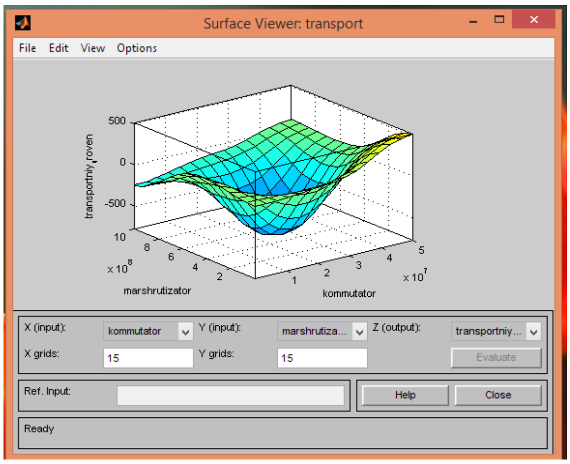


Figure 7. Results of simulation modeling of transport layer equipment

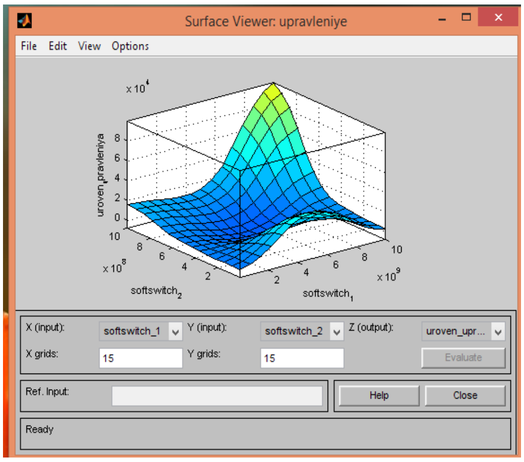


Figure 8. Results of simulation modeling of management layer equipment

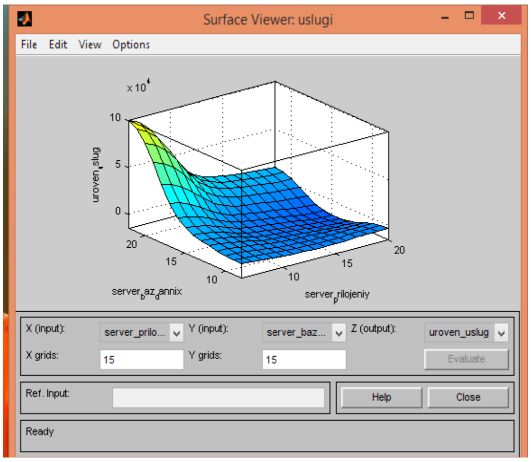


Figure 9. Results of simulation modeling of service layer equipment

5. CONCLUSION

In this scientific experiment, according to the input statistical applications, the parameters of the availability factor of network equipment of each level are sequentially calculated. Equipment has been identified for which the requirements of the required level of reliability parameter are not met. Next, the amount of the allocated amount is indicated for the type of technical operation "localization" and the operation of its distribution between the subscriber access level and the transport levels is performed. Each subsequent execution of the described operation determines an acceptable (optimal) resource allocation option that satisfies the requirement of the required level of reliability. The results of simulation modeling and a scientific experiment will allow the authors to further study the probabilistic and temporal parameters of an ICN network, taking into account the costs and expenses that arise during operation in certain sections of multiservice networks.

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REFERENCES

[1] E. Y. Kalimulina, "Reliability computation for complex systems with parallel structure that are completely repairable during use" *Automation and Remote Control*, vol. 71, pp. 1257–1264, 2010, doi: 10.1134/S0005117910060263.

[2] G. Wei, "System Reliability Modeling and Analysis of Distributed Networks", *Advanced Pattern Recognition Systems for Multimedia Data*, 2022, doi: 10.1155/2022/9719427.

[3] A. Muradova, "Calculation in the NGN networks of indexes of reliability of tracts of transmission of packet information," *The Advanced Science Journal*, pp. 24-28, 2014. [Online]. Available: https://web.archive.org/web/20170706013249id_/http://advancedscience.org/2014/2/024-028.pdf

[4] A. A. Muradova, "Modeling of decision-making processes to ensure sustainable operation of multiservice communication network", *Journal of ICT Research and Applications*, vol. 13, no. 1, pp. 50-62, 2019, doi: 10.5614/ITBJ.ICT.RES.APPL.2019.13.1.4.

[5] A. A. Muradova and A. F. Khaytbaev, "Analysis of the reliability of the components of a multiservice communication network based on the theory of fuzzy sets," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 19, no. 5, pp. 1715-1723, 2021, doi: 10.12928/TELKOMNIKA.v19i5.19854.

[6] A. A. Muradova, "Algorithm and program for calculating the structural reliability of the NGN network using method of statistic modeling," in *2013 International Siberian Conference on Control and Communications (SIBCON)*, 2013, pp. 1-4, doi: 10.1109/sibcon.2013.6693643.

[7] I. Demydov, Y. Klymash, M. Brych and M. Klymash, "The Structural-Functional Synthesis of IoT Service Delivery Systems by Performance and Availability Criteria," *Internet of Things (IoT) and Engineering Applications*, vol. 2, no. 1, pp. 1-13, 2017, doi: 10.23977/iotea.2017.21001.

[8] N. Pasieka *et al.*, "Designing Risk Resilient Networked High-Load Computing Web-Systems for Information Flow Processing," *CITRisk'2021: 2nd International Workshop on Computational & Information Technologies for Risk-Informed* Systems, 2021. [Online]. Available: https://ceur-ws.org/Vol-3101/Paper29.pdf

[9] D. W. Charltoni *et al.*, "An Avionic Gigabit Ethernet Network," in *2013 IEEE Avionics, Fiber-Optics and Photonics Technology Conference (AVFOP)*, 2013, pp. 17-18, doi: 10.1109/AVFOP.2013.6661601.

[10] Y. -K. Lin and L. C. -L. Yeng, "Evaluation of Network Reliability for Computer Networks with Multiple Sources," *Stochastic Systems: Modeling, Analysis, Synthesis, Control, and their Applications to Engineering*, 2012, doi: 10.1155/2012/737562.

[11] Y. -K. Lin and C. -T. Yeh, "Maximizing network reliability for stochastic transportation networks under a budget constraint by using a genetic algorithm," *International Journal of Innovative Computing, Information and Control*, vol. 7, no. 12, pp. 7033–7050, 2011. [Online]. Available: ijicic.org/ijicic-10-06021.pdf

[12] O. V. Lemeshko, O. Yevsyeyeva, and S. Garkusha, "Reliability Tensor Model of Telecommunication Network with RED," *R&I*, vol. 4, pp. 40-44, 2012. [Online]. Available: http://dspace.puet.edu.ua/bitstream/123456789/3488/1/Reliability-tensor-model-of-telecommunication-network-with-red.pdf

[13] B. Muminov, R. Nasimov, S. Mirzahalilov, N. Sayfullaeva, and N. Gadoyboyeva, "Localization and Classification of Myocardial Infarction Based on Artificial Neural Network," *Information Communication Technologies Conference (ICTC)*, 2020, pp. 245-249, doi: 10.1109/ICTC49638.2020.9123300.

[14] V. M. Pakhomova, "Network traffic forcasting in informationtelecommunication system of prydniprovsk railways based on neuro-fuzzy network," *Science and Transport Progress*, vol. 66, no. 6, pp. 105-114, 2016, doi: 10.15802/stp2016/90485.

[15] S. Gowrishankar and P. S. Satyanarayana, "A time series modeling and prediction of wireless network traffic," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 3, no. 1, pp. 53-62, 2008, doi: 10.3991/ijim.v3i1.284.

[16] V. I. Levin, "Evaluation of Reliability of Systems by Logical Methods," (in Russian), *Systems of Control, Communication and Security*, no. 2, pp. 182-195, 2017. [Online]. Available: https://sccs.intelgr.com/archive/2017-02/07-Levin.pdf

[17] M. G. Hasanovna, "About Quality of Optical Channels in Wavelength Division Multiplexing Systems of Optic Fibers," *Telecommunication Computing Electronics and Control (TELKOMNIKA*), vol. 16, no. 5, pp. 2005-2013, 2018, doi: 10.12928/telkomnika.v16i5.10300.

[18] J. Qin, Y. Niu, and Z. Li, "Reliability Modeling and Structure Importance Analysis of Electric Power Station Distribution Control System," *Information Technology Journal*, vol. 13, no. 16, pp. 2593-2601, 2014, doi: 10.3923/itj.2014.2593.2601.

[19] M. Yevdokymenko, M. Manasse, D. Zalushniy, and B. Sleiman, "Analysis of methods for assessing the reliability and security of infocommunication network," in *2017 4th International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S&T)*, 2017, pp. 199-202, doi: 10.1109/infocommst.2017.8246379.

[20] S. A. Sadchikova, A. V. Son, V. M. Son, and S. M. -Sek, "Model of telecommunication switching system design" in *2006 2nd IEEE/IFIP International Conference in Central Asia on Internet*, 2006, pp. 1-3, doi: 10.1109/canet.2006.279263.

[21] Z. Li *et al.*, "Study on the Reliability Evaluation Method and Diagnosis of Bridges in Cold Regions Based on the Theory of MCS and Bayesian Networks," *Sustainability*, vol. 14, no. 21, 2022, doi: 10.3390/su142113786.

[22] S. Ghasemnezhad and A. Ghaffari, "Fuzzy Logic Based Reliable and Real-Time Routing Protocol for Mobile Ad hoc Networks," *Wireless Personal Communications*, vol. 98, pp. 593-611, 2018, doi: 10.1007/s11277-017-4885-9.

[23] S. R. Vegesna, *IP Quality of Service*, 221 River Street, Hoboken: Cisco Press, 2001. [Online]. Available: https://www.ciscopress.com/store/ip-quality-of-service-9781578701162

[24] M. J. Zuo, Z. Tian and H. -Z. Huang, "An efficient method for reliability evaluation of multistate networks given all minimal path vectors," *IIE Transactions*, vol. 39, no. 8, pp. 811–817, 2007, doi: 10.1080/07408170601013653.

[25] J. E. R. -Marquez, D. W. Coit and M. Tortorella, "A generalized multistate-based path vector approach to multistate two-terminal reliability," *IIE Transactions*, vol. 38, no. 6, pp. 477–488, 2006, doi: 10.1080/07408170500341270.

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