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Analysis of Work Quality Indicators of Single-Server Computer Networks Providing Queued Service on First and Second Priority

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Annotation

- It has been shown that in a single-channel non-priority network with a limited queue, increasing the number of waiting spots has an insignificant effect on the probability of failures under low loads; however, as the loads increase with the same number of waiting spots, the probability of failures sharply rises.

- Method for calculating the quality indicators of node functioning in computer networks with prioritized servicing of incoming packet streams;

- An analytical model of a single-channel multi-node computer network with a limited queue and absolute priority, dependent on the number of network nodes, the number of waiting places in individual nodes, and the loads of the first and second priorities, has been developed. Application software packages have been created, which were used to perform calculations and build dependencies of failure probabilities for various values of individual priority loads, the number of network nodes, and the number of waiting places in individual nodes. It has been determined that in single-channel multi-node networks with limited queues and absolute priority, under the same load conditions, the quality of service for requests significantly deteriorates with an increasing number of nodes.

To ensure the desired level of service quality for requests, it is necessary to increase the number of waiting spots at individual network nodes. An analysis of a single-channel multi-node network with a limited queue and absolute priority shows that the quality of service for requests in such networks heavily depends on the load of individual priorities.

The provided numerical calculations and constructed dependency graphs make it possible to determine the required quality of operation of a specific computer network with a given number of nodes, the number of waiting places in specific nodes, and the values of first and second priority loads.

Keywords: service, computer network, calculation, load, number, waiting places, priority, mathematical models.

MATERIALS AND METHODS

Let's consider a single-channel queuing system (SQS) with **k** waiting places. Two streams of requests with intensities λ_1 and λ_2, respectively, enter the system. The arrival frequency of the streams follows a Poisson distribution. The service time distribution functions for the first and second priority requests are exponential [2];[3]. In this case, the intensity of the incoming

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load for the first and second priorities will be equal to ρ_1 and ρ_2, respectively. The first stream has absolute priority over the second stream.

For streams with equal priority, the FIFI (First in First Out) dispatching discipline is applied. The service of the stream is not interrupted. The streams are not discarded from the queue. At the same time, the parameters and characteristics for the queue to a single server are defined as:

$$\lambda = \lambda_1 + \lambda_2; \tag{1}$$

$$\rho_1 = \lambda_1 T_{s1}; \quad \rho_2 = \lambda_2 T_{s2}; \quad \rho = \rho_1 + \rho_2; \tag{2}$$

$$T_s = \frac{\lambda_1}{\lambda} T_{s1} + \frac{\lambda_2}{\lambda} T_{s2}; \tag{3}$$

$$T_r = \frac{\lambda_1}{\lambda} T_{r1} + \frac{\lambda_2}{\lambda} T_{r2}, \tag{4}$$

where λ - the intensity of the incoming request flow, that is, the average number of incoming requests per second;

$T_s -$ average handling time for each request;

$\rho -$ intensity of incoming total load.

$T_r -$ average time a request spends in the system.

Below are the formulas for the case when the service time is exponentially distributed [1-7]:

$$w_1 = \frac{\rho_1(\rho_1 T_{s1} + \rho_2 T_{s2})}{T_{s1}(1-\rho_1)}; \tag{5}$$

$$w_2 = w_1 \frac{\lambda_2}{\lambda_1[1-(\rho_1+\rho_2)]}; \tag{6}$$

$$T_{r1} = T_{s1} + \frac{\rho_1 T_{s1} + \rho_2 T_{s2}}{1+\rho_1}; \tag{7}$$

$$T_{r2} = T_{s2} + \frac{T_{r1} - T_{s1}}{1-(\rho_1+\rho_2)}, \tag{8}$$

where -- w_1 - the average number of first-priority requests waiting for service;

$w_2 -$ the average number of second-priority requests awaiting service;

$T_{r1} -$ average time that a first-priority request spends in the system;

T_{r2} – average time that a second-priority request spends in the system.

Taking into account the general formulas presented, formulas (6) and (8) can be represented in the following form:

$$w_2 = w_1 \frac{\rho_2 T_{s1}}{\rho_1 T_{s2}\left[1-\left(\rho_1+\rho_2\right)\right]}; \tag{9}$$

$$T_{r2} = T_{s2} + \frac{T_{r1}-T_{s1}}{1-(\rho_1+\rho_2)}. \tag{10}$$

Calculations based on the obtained formulas were performed for various values of first and second priority loads. It is assumed that the average service time for a first priority packet is $T_{s1} = 0{,}01$ seconds.

The average service time for the second priority packet is $T_{s2} = 10.T_{s1} = 0{,}1$ sec. For obtaining numerical calculations and constructing graphs, the program **Excel 2019** was used. In Fig. 2.4, the dependence of the average delivery time of first-priority requests (T_{r1}) on the loads of the first priority (ρ_1) for certain values of the loads of the second priority (ρ_2) is presented. In Fig. 1, the dependence of the average delivery time of second-priority requests (T_{r2}) on the loads of first-priority requests (ρ_1) for certain values of second-priority loads (ρ_2) is shown.

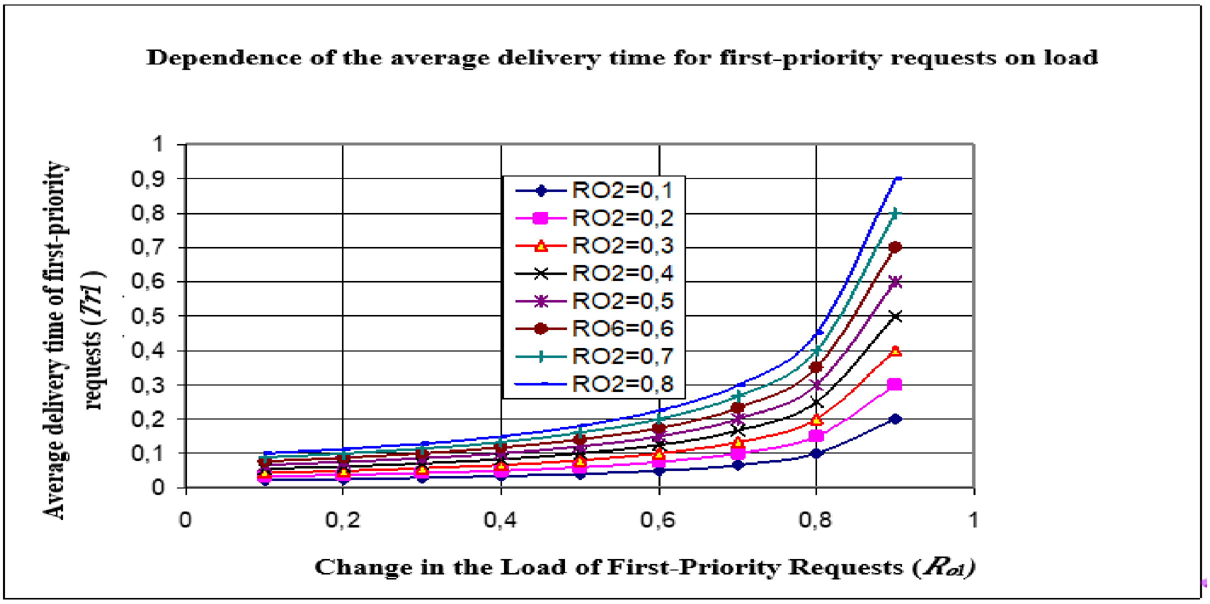

Fig. 1. Dependence of the average delivery time of first-priority requests (T_{r1}) on the loads of the first priority (ρ_1) for specific values of the loads of the second priority (ρ_2)

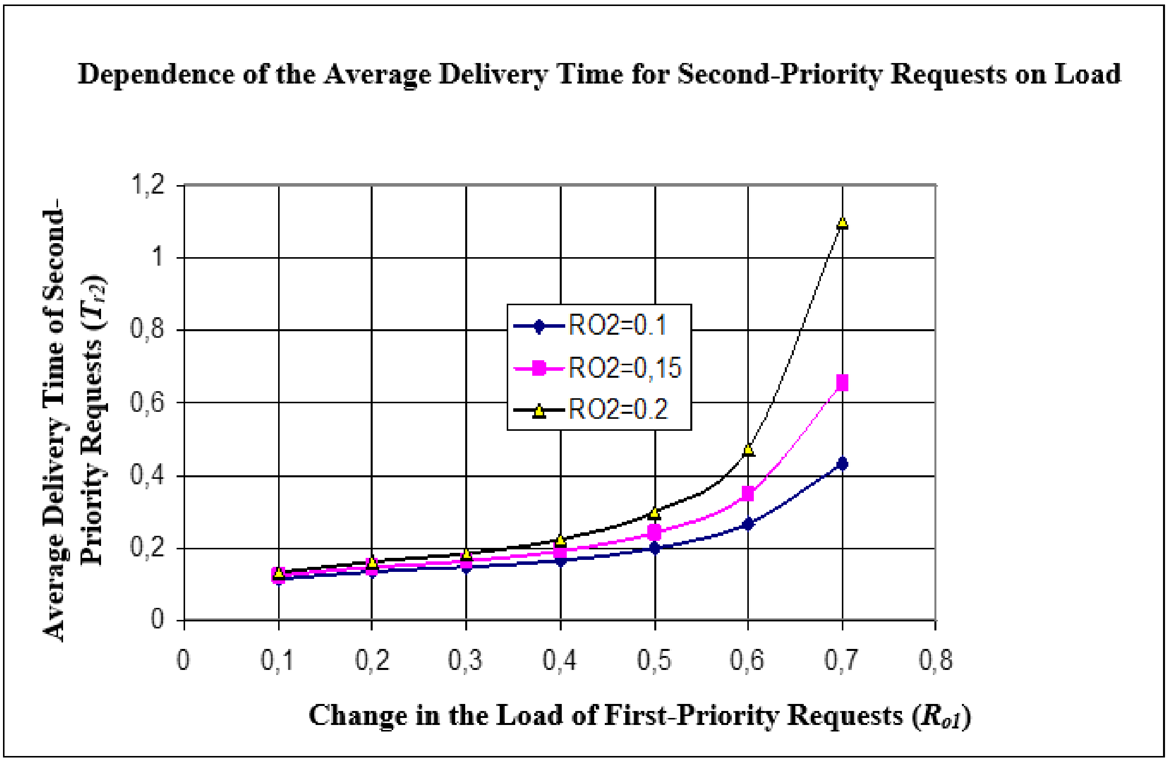

Fig. 2. Dependence of the average delivery time of second-priority requests (T_{r2}) on the loads of first-priority requests (ρ_1) for specific values of second-priority loads (ρ_2)

The analyses show that the servicing of high-priority packets is performed significantly faster than that of low-priority packets. The analyses of Figures 1 and 2 indicate that as the load values of the first priority increase, the average delivery time of requests for both the first and second priorities sharply rises.

For example, for values ρ_2 =0,8 and ρ_1 =0,8, the average delivery time for the first priority is T_{r1} =0.45 seconds, while for ρ_1 =0,7 and the load values of the second priority ρ_2 = 0.2, the average delivery time for the second priority T_{r2} =1,1 сек. is

RESULTS AND DİSCUSSİONS

Let's consider the functioning of a single-channel, single-node telecommunication network with a limited queue and absolute priority. The intensity of incoming traffic for the first and second priorities is equal to ρ_1 and ρ_2, respectively, with stream number 1 having absolute priority over stream number 2.

Using [2] for a single-channel and single-node computer network with a limited queue and absolute priority, the following dependencies characterizing the network's functioning have been obtained:

The probability of rejection for first-priority requests due to queue service constraints:

$$P_{01} = \rho_1^{k+1}\left[1+\rho_1\left(1+\sum_{i=1}^{k}\rho_1^{i}\right)\right]^{-1}, \tag{11}$$

where $\rho_1 -$ is the first priority load;
$k-$ number of waiting spots:

The probability of service denial for second-priority requests is equal to the probability that there are already k first and/or second-priority requests in the queue:

$$P_{02} = \left(\rho_1 + \rho_2\right)^{k+1}\left[1 + \left(\rho_1 + \rho_2\right)\left(1 + \sum_{i=1}^{k}\left(\rho_1 + \rho_2\right)^i\right)\right]^{-1}, \tag{12}$$

where $\rho_2 -$ is the second-priority load.

Table 1.

The probability of rejections for first-priority requests in a single-channel single-node system (N=1) with a varying number of waiting places (k=2-26)

ρ_1	**k=2**	**k=4**	**k=6**	**k=8**	**k=10**	**k=14**	**k=18**	**k=22**	**k=26**
0,1	0,0009	9,00E-06	9,00E-08	9,00E-10	9,00E-12	9,00E-16	9,00E-20	9,00E-24	9,00E-28
0,2	0,0064	0,000256	1,02E-05	4,10E-07	1,64E-08	2,62E-11	4,19E-14	6,71E-17	1,07E-19
0,3	0,0191	0,001702	0,00015	1,38E-05	1,24E-06	1,00E-08	8,14E-11	6,59E-13	5,34E-15
0,4	0,0394	0,006169	0,00098	0,00016	2,52E-05	6,44E-07	1,65E-08	4,22E-10	1,08E-11
0,5	0,0667	0,015873	0,00392	0,00098	0,000244	1,53E-05	9,54E-07	5,96E-08	3,73E-09
0,6	0,0993	0,032626	0,01139	0,00406	0,001454	0,000188	2,44E-05	3,16E-06	4,09E-07
0,7	0,1354	0,057144	0,02622	0,01246	0,006015	0,001429	0,00034	8,21E-05	1,97E-05
0,8	**0,1734**	**0,088819**	**0,0504**	**0,03007**	**0,018448**	**0,007241**	**0,00292**	**0,00119**	**0,00048**
0,9	0,212	0,126023	0,08398	0,05948	0,043732	0,025272	0,01538	0,00963	0,00614
1	0,25	0,166667	0,125	0,1	0,083333	0,0625	0,05	0,04167	0,03571

Table 2.
The probability of failures for first-priority requests in a single-channel multi-node system (N=2) with a varying number waiting areas (k=2-26)

ρ_1	**k=2**	**k=4**	**k=6**	**k=8**	**k=10**	**k=14**	**k=18**	**k=22**	**k=26**
0,1	0,0018	1,80E-05	1,80E-07	1,80E-09	1,80E-11	1,80E-15	1,80E-19	1,80E-23	1,80E-27
0,2	0,0128	0,000512	2,05E-05	8,19E-07	3,28E-08	5,24E-11	8,39E-14	1,34E-16	2,15E-19
0,3	0,0381	0,003404	3,06E-04	2,76E-05	2,48E-06	2,01E-08	1,63E-10	1,32E-12	1,07E-14
0,4	0,0788	0,012339	1,97E-03	3,15E-04	5,03E-05	1,29E-06	3,30E-08	8,44E-10	2,16E-11
0,5	0,1333	0,031746	7,84E-03	1,96E-03	4,88E-04	3,05E-05	1,91E-06	1,19E-07	7,45E-09
0,6	0,1985	0,065252	2,28E-02	8,11E-03	2,91E-03	3,76E-04	4,88E-05	6,32E-06	8,19E-07
0,7	0,2708	0,114288	5,24E-02	2,49E-02	1,20E-02	2,86E-03	0,00068	1,64E-04	3,94E-05
0,8	0,3469	0,177639	1,01E-01	6,01E-02	3,69E-02	1,45E-02	0,00583	0,00237	0,00097
0,9	0,424	0,252045	1,68E-01	1,19E-01	8,75E-02	5,05E-02	0,03076	0,01926	0,01227
1	0,5	0,333333	2,50E-01	2,00E-01	1,67E-01	1,25E-01	0,1	0,08333	0,07143

Table 3.

The probability of failures for first-priority requests in a single-channel multi-node system (N=3) with varying numbers waiting areas (k=2-26)

ρ_1	k=2	k=4	k=6	k=8	k=10	k=14	k=18	k=22	k=26
0,1	0,003	2,70E-05	2,70E-07	2,70E-09	2,70E-11	2,70E-15	2,70E-19	2,70E-23	2,70E-27
0,2	0,019	0,000768	3,07E-05	1,23E-06	4,92E-08	7,86E-11	1,26E-13	2,01E-16	3,22E-19
0,3	0,057	0,005107	0,00046	4,13E-05	3,72E-06	3,01E-08	2,44E-10	1,98E-12	1,60E-14
0,4	0,118	0,018508	0,00295	0,00047	7,55E-05	1,93E-06	4,95E-08	1,27E-09	3,24E-11
0,5	0,2	0,047619	0,01176	0,00293	0,00073	4,58E-05	2,86E-06	1,79E-07	1,12E-08
0,6	0,298	0,097879	0,03417	0,01217	0,00436	0,000564	7,31E-05	9,48E-06	1,23E-06
0,7	0,406	0,171432	0,07865	0,03737	0,01805	0,004287	0,00103	2,46E-04	5,91E-05
0,8	0,52	0,266458	0,1512	0,09022	0,05534	0,021722	0,00875	0,00356	0,00145
0,9	0,636	0,378068	0,25194	0,17845	0,1312	0,075816	0,04613	0,02889	0,01841
1	0,75	0,5	0,375	0,3	0,25	0,1875	0,15	0,125	0,10714

In Fig. 3, the dependencies of the probability of service failures for first-priority requests (P_{01}) at different numbers of waiting spots (k) are presented.

Table 1 presents the results of calculations of service denial probabilities for first-priority requests in a single-channel and single-node network (N=1) with varying numbers of waiting places (k=2-26).

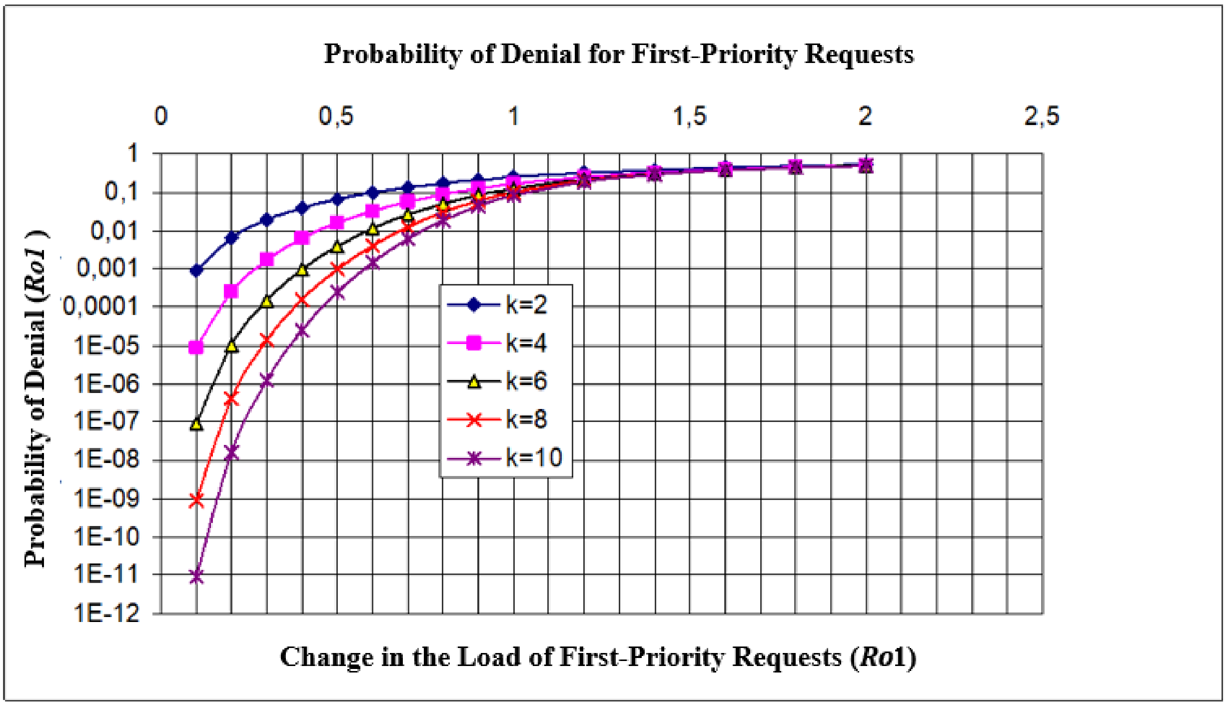

Fig. 3. Dependence of the probability of service failures for first-priority requests on first-priority loads (ρ_1) for specific values of second-priority loads (ρ_2)

From Fig. 3, it can be seen that in a single-channel single-priority network, the impact of increasing the number of waiting places . **(k)** on the probability of failures is significant at low load values (ρ_1) and becomes negligible at ρ_1 **>0.8**.

For example, under load ρ_1 **=0,4** and **k=2**, the probability of failure P_{01} **=0.05**, and under load ρ_1 **=0,4** and **k=6**, the probability of failure P_{01} **=0.00001**. Under load ρ_1 **=0,8**, under **k=2** the probability of failure P_{01} **=0.1**, under **k=6** the probability of failure P_{01} **=0.03**.

Figure 4 shows the results of calculations of the probability of service refusals for second-priority requests (P_{02}) with different numbers of waiting places (k) and second-priority loads (ρ_2=0.8).

In Table 2 and Table 3, the results of the calculations of the blocking probabilities for second-priority requests in a single-channel, single-node network (N=1) with varying numbers of waiting places (k=2-26) and second-priority loads are presented.

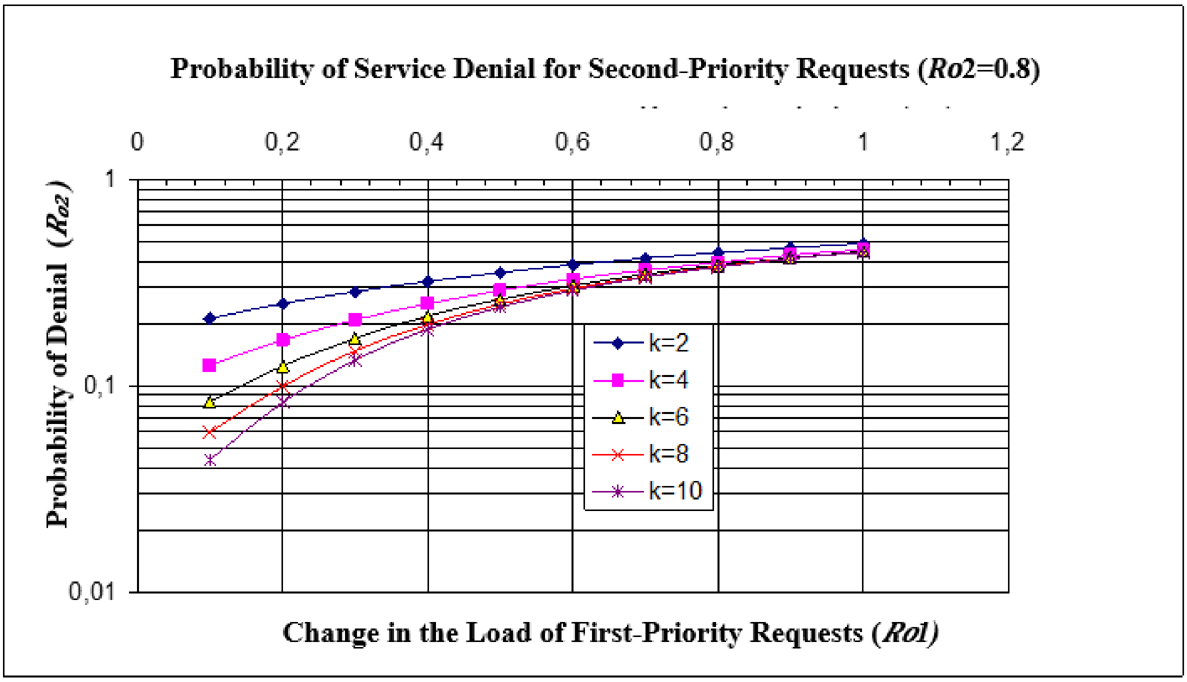

Fig. 4. Dependence of the probability of service failures for second-priority requests on first-priority loads (ρ_1) for a given value of second-priority load (ρ_2 =0,8)

From Fig. 4, it can be seen that in a single-channel network with two-priority servicing, to ensure the required failure probability, the load of the second priority (ρ_2) must be reduced with an increase in ρ_2, while the load of the first priority (ρ_1) must be decreased. For example, with ρ_2 =0,8; ρ_1 =0.2 and k=10, the probability of failure for the second priority is P_{02} =0,08. In a single-channel network, with the overall load of the first and second priorities ($\rho_1 + \rho_2$)>1, it is impossible to ensure the required failure probability by increasing the number of waiting places (k), therefore the need arises to create a multi-channel network.

CONCLUSION

- The proposed mathematical models allow for determining the dependencies of the average delivery time of first-priority (second-priority) requests on the loads of the first and second priorities. As the values of the first-priority loads increase, the average delivery time of first-priority and second-priority requests sharply rises.
-In a single-channel non-priority network with a limited queue, the impact of increasing the number of waiting places (k) on the probability of failures is negligible at low loads; however, as the load increases with the same number of waiting places, the probability of failure rises sharply.
- In single-channel multi-node networks with limited queues, under the same load conditions, as the number of nodes increases, the quality of service for requests significantly deteriorates. To ensure the desired level of service quality for requests, it is necessary to increase the number of waiting places at individual nodes in the network.
- A mathematical model of a single-channel multi-node computer network with a limited queue and absolute priority has been proposed, which allows determining the quality of functioning of such a network, depending on the number of waiting places in individual nodes and the loads of individual priorities.
- The analysis of a single-channel multi-node network with a limited queue and absolute priority shows that the quality of service for requests in such networks heavily depends on the load of individual priorities. The provided numerical calculations and proposed graphical dependencies make it possible to determine the required quality of operation for a specific computer network with a given number of nodes, the number of waiting places in specific nodes, and the load values of the first and second priorities.

Discussion: Discussing the results and comparing them with the findings of other researchers plays an undeniable role in advancing scientific knowledge and understanding of complex issues of communication network performance. Analysing the data obtained in the previous sections and comparing them with the conclusions of other researchers, it is possible to identify common patterns, key differences, and additional aspects of this problem.

The research problem lies in the search for optimal solutions to ensure the efficient operation of communication networks under various load and traffic conditions. The growth in the number of users, the active use of online services and other factors create a load on network resources and can lead to a decrease in the quality and speed of service to network users.

The study by A. Tanenbaum and D. Wetherall explored the impact of load growth on the performance of communication networks [1]. They analysed various aspects, including bandwidth and latency, and drew conclusions about effective methods of optimising networks to ensure stable performance. The details of the use of real network loads in different applications were not sufficiently disclosed.

Huseynov Z.N, Mammadov M.I.,Ismayilov T.A. Modelingand analysis of the characteristics of multichannel and multi-node computer networks with priority service. Investigated methods for increasing network bandwidth by optimising resources at different network levels, but did not sufficiently examine the impact of different types of data on the optimisation results [2].

The main purpose of the study of the document authored by Z. Huseynov*, T. Ismayılov, S. Babayeva, S. Baratzade, N. Baratzade et al. [3] The subject of the study is analytical models and methods for calculating the quality indicators of the functioning of computer networks with priority services. Mathematical methods of the theory of queuing systems provide the ability to solve numerous problems of calculating the characteristics of the quality of functioning of various components of computer networks. The resulting tables and functional dependencies make it possible to design a computer network operating with the required quality indicators.

Previous research in this industry has already discovered some aspects and approaches to solving communication network performance problems. For example, L. Peterson and B. Davie investigated the effect of routing protocols on network performance, showing that some protocols may be more efficient in large networks, and some may interfere with the fast operation of the network [4]. Insufficient attention was paid to the issue of the impact of changing conditions within the network on the effectiveness of different network protocols.

The main research point of the paper authored by Z. Huseynov [5] is modeling and analysing the features of computer networks with prioritized services, analyzed indicators modeling and optimization of a computer corporate network with priority service "Elections". The urgency of designing corporate computer networks and providing quality of service (QoS - Quality of Service) is based on the fact that the work was carried out in accordance with the design plan of the State Automated Information System "Elections" and the application new equipment and technology. The purpose of the work: development of methods for calculatingthe probability denial of the flood inquiries in corporate computer networks and the probability of timely delivery preparation proposals on the selection and effective use telecommunications equipment when creating corporate computer networks development methods for optimizing the parameters of telecommunication nodes operating with different service systems. Using analytical models of a computer corporate communication network, the probabilities loss and timely delivery of requests are determined. The work of the corporate com-munication network "Elections" of the Republic of Azerbaijan has been studied.

The main distinguished feature of modern telecommunication networks Z. Huseynov [6] is the delivery of various types of information packets to the destination point on various routes. The main purpose of this study is to determine the dependence of packet loss on downloads and network resources. Mathematical models for calculating the probability of service failures in multichannel single node and multichannel multi node networks with a limited queue and absolute priority are proposed.

The paper by Fuente Maria Jose Pardo, David de la Fuente. Optimizing a priority-discipline queueing model using fuzzy set theory. Investigates the possibilities of improving the performance of communication networks by optimising routing [7].

R. Ghimire and R. Noor [8] present two approaches to the study – quantitative and qualitative. The quantitative approach is aimed at analysing the results obtained as a result of experiments, surveys, or simulations, while the qualitative approach is aimed at obtaining a deeper understanding of the problem. The researchers also note the importance of studying the literature to understand the main problems in the field of research. The study of literature is indeed an important stage of research, and the use of both quantitative and qualitative approaches can be useful to get a complete picture of the problem. The researcher analyses the problem and considers the available resources using a qualitative approach. In conclusion, the author suggests further work on the application of the proposed RED algorithm in real time to compare the simulation results with real data. Thus, a comprehensive approach to the investigation of the problem, using both qualitative and quantitative methods, is presented, and the importance of studying the literature to understand the main problems in the field of research is emphasised. The study considers the effectiveness of quality of service (QoS), which is also the basis of this paper. O. Bonaventure [9] provided a comprehensive insight into the principles, protocols, and practices of computer networks. The book is intended for students who want to learn about computer networks, and covers all the material for the first semester course on network technologies for undergraduate or postgraduate students. The author discusses changes in the approach to teaching computer networks in connection with the development of the Internet and the availability of a large amount of information. The researcher notes that today's students are experienced Internet users and can easily check the information received from teachers due to the availability of information on the Internet. The author also notes that there are many challenges for teachers related to teaching students in conditions of availability of a large amount of information. One of the interesting points is the mention that the authors of textbooks on computer networks have begun to revise their approach to learning, starting with the applications that students use, and then explaining the Internet protocols, removing one level after another. This kind of work is a general set of knowledge about the work of the Internet, which is suitable for study by both students and people of a higher technical level.

S. Prakash explored the possibility of using cloud technologies to optimise the performance of communication networks [10]. The researcher analysed the advantages and limitations of this approach and made recommendations for their implementation. The paper omitted the issue of the efficiency of cloud storage in conditions of using large amounts of data and a high level of load on them.

The document [11] authored by M. Kartashov is a mathematical reference book specialising in the section of probability theory. In particular, this source describes the Poisson distribution law, which simplifies the process of calculating the applied characteristics of the network induced in this work.

The paper by H. Khazei [12] describes a model for analysing the performance of data processing centres in cloud computing. The model is designed to analyse the performance of data processing centres with different requests and resources using interacting stochastic models. The document describes the main characteristics of the analytical model, such as the assumption of Poisson arrival of user requests, support for the high degree of virtualisation, consideration of various delays imposed by data processing centres on user requests, and the characterisation of service availability at the data processing centre. The researchers also discuss the importance of considering the maintenance time of virtual machine (VM) tasks on loaded PM, since the maintenance time of tasks increases with the increase in the total load on PM. They suggest using a probability distribution that allows adjusting the coefficient of variation (CoV) independently of the average value to take this factor into account. The author of this study agrees that the consideration of the maintenance time of tasks on busy PM is an important factor for evaluating the performance of cloud computing centres. However, for a more accurate performance assessment, other factors must also be consider, such as the use of different types of VM, network settings, etc. In general, the paper presents an interesting model for evaluating the performance of cloud computing centres, which can be useful for cloud service providers. However, for a more accurate performance assessment, it is necessary to take into account other factors that may affect the performance of cloud computing centres.

The main purpose of the study by L. Yangyong [13] is the use of genetic algorithms to optimise the planning of the distribution network in order to reduce electricity losses. The paper explores how to intelligently optimise the plan by extracting relevant, analysing examples and experimental data, obtaining some data to simulate a real situation using sandbox modelling and genetic algorithm modelling. The thesis that a genetic algorithm can be an effective tool for optimising the planning of power distribution networks is quite interesting and innovative. For more accurate optimisation, it is necessary to take into account not only energy losses, but also other factors such as cost and environmental consequences. In addition, more sophisticated machine learning algorithms, such as neural networks, need to be used for more accurate results. In general, the authors' research is interesting and important in the context of optimising power distribution networks. However, for more accurate results, additional factors must be considered and more complex machine learning algorithms must be used. In the context of this study, the analysis of electrical networks can serve as a basis for monitoring the efficiency of computer networks, the principle of operation of which is similar.

The study by L. Limiao et al. [14] is devoted to optimising cost management for network services, namely, minimising costs and maximising network utility. The document also discusses the problems of energy consumption and data transmission in WBAN networks, and also offers a framework for capturing the stochastic process of energy saving. The researchers emphasised that energy management is an important issue in wireless sensor networks. Using the sleep/wake mode control algorithm can help to increase the operating time of devices and reduce power consumption. In addition, ensuring data integrity is critical to provide the correct operation of the system. This paper offers its own view on the use of electrical resources by networks, which can be applied, in particular, to computer networks.

The main research topic of the book by L. Kleinrock [15] is the creation of a mathematical theory of computer networks, which eventually led to the development of the Internet. The author discusses the key concepts that have made the Internet network technology so powerful, including on-demand access, large shared systems, and distributed management. The author also describes the nature of data transmission and the problems that had to be overcome in order to develop a convincing body of knowledge confirming the need for data transmission networks. Additionally, the author addresses the issue of optimal design of these networks, paying special attention to the choice of bandwidth of each channel, the choice of routing procedures, and topological design. The development of a mathematical model is indeed an important step in optimising the performance of computer networks, and in its course, it is necessary to consider all possible indicators, risks, and limitations. The research is also related to network performance optimisation, and therefore, the ideas presented by L. Kleinrock are interesting, in particular, for this study.

The paper by R. Lyer and L. Kleinrock [16] discusses the problem of ensuring the required quality of service in wireless sensor networks with all kinds of restrictions that may arise in such networks. Due to limited resources such as computing power, memory, bandwidth, and power supplies in sensor networks, providing quality of service in wireless sensor networks is a challenging task. The paper discusses the features of wireless sensor networks that pose problems for quality of service and provides an overview and comparative analysis of routing protocols focused on quality of service in wireless sensor networks. The document also discusses approaches to ensuring the quality of service in wireless sensor networks (WSN) using middleware. At the conclusion of the document, some open problems and directions of future research for ensuring the quality of service in wireless sensor networks are indicated. It is possible to agree with the researchers that ensuring QoS in WSN is a difficult task due to limited resources and the dynamism of the network. However, the authors could consider in more detail the problems associated with data security in the WSN, since this is also an important aspect of QoS provision. In general, the paper is of interest to researchers working in the field of WSN and QoS. It can also be useful for developers who want to create applications using WSN.

The main purpose of the study by R. de Moraes and F. Vasques [17] is to propose and analyse solutions that allow implementing network management systems supported by networks with uncontrolled access, such as packet-switched networks. The paper discusses the assessment of different communication methodologies on the quality of service provided to a particular management application and the influence of communication parameters on management stability. The document also highlights the problems of implementing control systems in distributed, asynchronous network environments and constructing dependable systems from components that may lack reliability. The implementation of network-based management systems that do not require access control is an important task in the management of large-scale communication systems and network-based management systems. However, it is worth noting that some aspects, such as security and data protection in network-based management systems that do not require access control, have not been considered in this paper. Although these aspects are not considered in the context of this study, they are also important and should be taken into account when implementing such systems.

The paper authored by K. Rege [18] is devoted to the theory of multiclass queues and its application in the analysis of the performance of computer systems. The paper presents the outcomes of analytical investigations, along with instances illustrating the application of these findings in practical systems. Models of multiclass queues are described, which allow analysing computer systems with different types of resources and transactions. The paper also discusses the constraints and challenges linked to utilizing such models and suggests methods and approximations to solve them. The author of this study agrees that analytical queue models can be very useful for evaluating the performance of computer systems. However, these models have their limitations and approximate methods and simulations may be necessary to evaluate the performance of more complex systems.

The research carried out in this paper is also related to the analysis of the performance of computer systems, and, therefore, the paper provides valuable information for researchers in this field. Especially interesting is the example which illustrates how analytical results can be used together with approximate methods and simulations to evaluate the performance of complex systems.

Summing up, when analysing the results of this study and comparing them with the findings of other researchers, the importance of an integrated approach to analysing the performance of communication networks is emphasised. Single factors are not sufficient to fully understand the complex dynamics of networks. The conclusions of this study enrich and expand the existing knowledge in this field, providing a deeper understanding of the impact of different parameters on the effectiveness of communication networks. It is crucial to emphasize that the main focus of this study is on the hardware component of computer networks, which is not the only one affecting its speed and efficiency.

The main distinguished feature of modern telecommunication networks is the delivery of various types of information packets to the destination point on various routes. The main purpose of this study is to determine the dependence of packet loss on downloads and network resources. Mathematical models for calculating the probability of service failures in multichannel single node and multichannel multi node networks with a limited queue and absolute priority are proposed.

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