http://doi.org/10.35784/iapgos.3394

received: 29.12.2022 | revised: 28.03.2023 | accepted: 27.04.2023 | available online: 30.06.2023

MODELING AND ANALYSIS OF THE CHARACTERISTICS OF MULTICHANNEL AND MULTI-NODE COMPUTER NETWORKS WITH PRIORITY SERVICE

Zakir Nasib Huseynov, Mahil Isa Mammadov, Togrul Atabay Ismayilov
Azerbaijan State Agricultural University, Ganja, Azerbaijan

Abstract. *The subject of the research is modeling and analysis of the characteristics of multichannel and multi-node computer networks with priority services. The work is devoted to the study of the qualitative indicators of the functioning of computer networks with priority service. In this work, mathematical models are developed that make it possible to assess the quality of functioning of modern computer networks, taking into account the number of channels, waiting places in network nodes and the number of network nodes. The proposed methods for calculating the probability of failures and the probability of timely delivery of a stream of requests make it possible to determine the real values of the qualitative indicators of the functioning of computer networks and are suitable for both designed and operating computer networks. The proposed technique makes it possible to determine the number of packets in the queue and the optimal amount of buffer memory in computer network nodes.*

Keywords: multichannel, multi-node, probability, priority, algorithm, buffer memory

MODELOWANIE I ANALIZA CHARAKTERYSTYK WIELOKANAŁOWYCH I WIELOWĘZŁOWYCH SIECI KOMPUTEROWYCH Z USŁUGĄ PRIORYTETOWĄ

Streszczenie. *Przedmiotem badań jest modelowanie i analiza charakterystyk wielokanałowych i wielowęzłowych sieci komputerowych z usługami priorytetowymi. Praca poświęcona jest badaniu jakościowych wskaźników funkcjonowania sieci komputerowych z usługami priorytetowymi. W pracy opracowano modele matematyczne umożliwiające ocenę jakości funkcjonowania nowoczesnych sieci komputerowych z uwzględnieniem liczby kanałów, miejsc oczekiwania w węzłach sieci oraz liczby węzłów sieci. Proponowane metody obliczania prawdopodobieństwa awarii i prawdopodobieństwa terminowego dostarczenia strumienia żądań umożliwiają określenie rzeczywistych wartości wskaźników jakościowych funkcjonowania sieci komputerowych i są odpowiednie zarówno dla projektowanych, jak i działających sieci komputerowych. Proponowana technika umożliwia określenie liczby pakietów w kolejce i optymalnej ilości pamięci buforowej w węzłach sieci komputerowej.*

Słowa kluczowe: wielokanałowy, wielowęzłowy, prawdopodobieństwo, priorytet, algorytm, pamięć buforowa

Introductıon

The article shows a mathematical model of a multi-channel, multi-node computer network with a limited queue and absolute priority, depending on the number of network nodes, waiting places in individual nodes and the probability of failure of requests of individual priorities. It is shown that in multichannel, multi-node computer networks, to ensure the required quality of functioning, it is necessary to choose the optimal number of channels (s), waiting places (k) in the network nodes and the load of individual priorities (ρ_1, ρ_2). It was revealed that with an increase in the number of network nodes (N), it becomes necessary to increase the number of channels (s) and waiting places (k) in the network nodes. The resulting tables and functional dependencies make it possible to design a computer network that functions with the required quality indicators. In [8] and [9] article, the calculation is performed in single-channel multi-node families, the probability of failure for requests of the first and second priorities with a limited service queue. In contrast to [8] and [9], the proposed calculation methods make it possible to determine the delivery time, the number of packets in the queue, the probability of request flow failures in multi-channel multi-node computer networks with a limited queue and absolute priority.

The operation of an analytical model of a computer corporate network is studied, the probabilities of loss and timely delivery of requests are determined. The work of the computer corporate network "SEÇKİLƏR" of the Republic of Azerbaijan has been studied [7].

1. Materials and methods

In computer networks based on modern technologies, voice and text information are exchanged digitally in the form of packets. Due to the limited network resources, there is a delay and loss of packets, which leads to an increase in the quality of service. In practice, computer networks with different architectural structures are used [1]. As shown in figure 1, there are cases when a network consists of dozens of nodes and one or more parallel communication channels connecting these nodes to each other in a certain order.

Computer networks and various types of information's are divided into packets and transported from one address to another for exchange between network operators. As a rule, at the first node of the network, the information is processed by dividing it into packets. The processed individual packets are transported from these nodes to the required address in different ways, depending on the addresses written on them. In the process of transportation, packets may be forced to pass through several nodes of the network, which is due to the limited and busy communication channels between nodes. When packets are processed at nodes, they may be delayed due to delays, and new routes and high priority may be established to service them. Let's consider the activity of a computer network with an arbitrary structure when prioritizing packages [3].

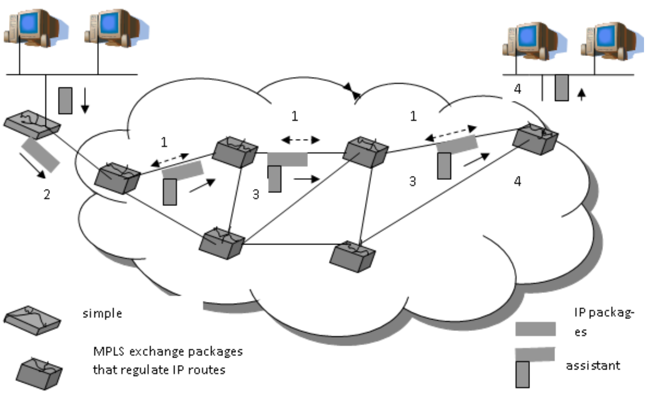


Fig. 1. The structure of using protocols and packages in prospective multi-channel, multi-node computer networks

In this paper, the characteristics of such a network are optimized in terms of QoS.

Let us consider a multichannel queuing system (QS) with waiting places. The system receives two streams of requirements with intensities and respectively [4] The distribution functions of the service time for the first and second priority requirements are exponential with the parameter. In this case, the intensity of the incoming load of the first and second priorities will be respectively equal to and. The first thread has absolute priority over the second thread.

In multichannel single-node computer networks with a limited queue and absolute priority, the probability of failure for the first priority request flow due to the limited queue in service is determined by the following dependence [5]:

$$P_1 = \frac{\rho_1^{s+k}}{s^k s!}\left[\sum_{\nu=0}^{s}\frac{\rho_1^{\nu}}{\nu!}+\frac{\rho_1^{s}}{s!}\sum_{j=1}^{k}\left(\frac{\rho_1}{s}\right)^{j}\right]^{-1} \quad (1)$$

where: S – is the number of channels; k – number of waiting places; ρ_1– load of the first priority.

With S = 1, it is possible to obtain a dependency for a single-channel network with a limited queue and absolute priority.

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

$$P_2 = \frac{(\rho_1+\rho_2)^{s+k}}{s^k s!}\left[\sum_{\nu=0}^{s}\frac{(\rho_1+\rho_2)^{\nu}}{\nu!}+\frac{(\rho_1+\rho_2)^{s}}{s!}\sum_{j=1}^{k}\left(\frac{\rho_1+\rho_2}{s}\right)^{j}\right]^{-1} \quad (2)$$

where: ρ_1 – is the load of the first priority; ρ_2 – load of the second priority.

An algorithm for solving the problem was developed for the calculation. In Fig. 2. an algorithm for calculating the probability of denial of service for requests of the first and/or second priorities in a multichannel single-node network is presented. The calculation according to this algorithm was performed using the Excel 2019 program.

Let's move on to obtaining a mathematical model for a multi-channel multi-node network. To obtain a mathematical model, you can use the position of probability theory and mathematical statistics. According to which, a sequence of random events is called monotonically increasing (non-decreasing) or monotonically decreasing (non-increasing), if for each The union of all events of such a sequence will be written as [2]:

$$\sum_{i=1}^{\infty} A_i = \lim_{i\to\infty} A_i \text{ or } \prod_{i=1}^{\infty} A_i = \lim_{i\to\infty} A_i \quad (3)$$

Since in multi-channel multi-node computer networks with a limited queue and absolute priority, the probability of failure increases with an increase in the number of switching nodes used, taking into account (3) from expressions (1) and (2) for single-priority and two-priority services, the following mathematical models can be obtained to calculate the probability failures in multichannel multi-node computer networks.

If we consider the probabilities of node failures to be the same, then the mathematical model for determining the probability of failure in multi-channel multi-node computer networks for first-priority requests due to a limited service queue has the following form:

$$P_{1m} = \sum_{i=1}^{N}\frac{\rho_{i_1}^{s_i+k_i}}{s_i^{k_i} s_i!}\left[\sum_{\nu=0}^{s_i}\frac{\rho_{i_1}^{\nu}}{\nu_i!}+\frac{\rho_{i_1}^{s}}{s_i!}\sum_{j=1}^{k_i}\left(\frac{\rho_{i_1}}{s_i}\right)^{j}\right]^{-1} \quad (4)$$

where: N – is the number of network nodes; ρ_i – the load of the first priority, s_i – the number of channels, k_i – the number of waiting places; i – the th network node.

If we consider the probabilities of node failures to be the same, the mathematical model of the probability of failures in multi-channel multi-node computer networks for second-priority requests due to a limited-service queue will have the following form:

$$P_{2m} = \sum_{i=1}^{N}\frac{(\rho_{i1}+\rho_{i2})^{s_i+k_i}}{s_i^{k_i} s_i!}\left[\sum_{\nu=0}^{s_i}\frac{(\rho_{i1}+\rho_{i2})^{\nu}}{\nu!} + \frac{(\rho_{i1}+\rho_{i2})^{s_i}}{s_i!}\sum_{j=1}^{k_i}\left(\frac{\rho_{i1}+\rho_{i2}}{s_i}\right)^{j}\right]^{-1} \quad (5)$$

where: ρ_{i2} – is the load of the second priority i-the network node.

2. Results and discussions

When designing a specific communication network, it is necessary to take into account the real probability of failures of the designed network nodes [6]. The calculation was performed according to the algorithm shown in Fig. 2.

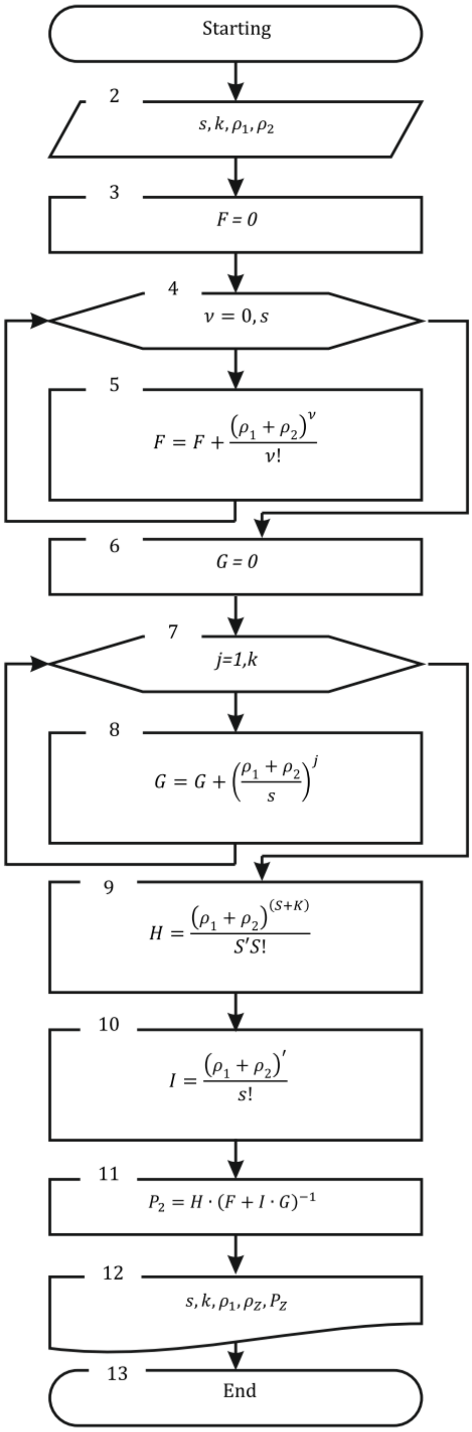


Fig. 2. Algorithm for calculating the probability of denial of service for requests of the first and / or second priority

Calculations based on the obtained models were performed for a different number of network nodes (N), the number of waiting places (k) and parallel channels (S). When obtaining numerical calculations and plotting, the Excel 2019 program was used.

Table 1. The results of calculating the probability of denial of service for requests of the second priority with a different number of N; k; ($s = 2; \rho_2 = 0.8$)

	P2m								
	N = 1			N = 2			N = 3		
	k = 14	k = 18	k = 20	k = 20	k = 24	k = 26	k = 24	k = 26	k = 28
0.2	1.02E-05	6.4E-07	1.59E-07	3.2E-07	1.99E-08	4.97E-09	2.98E-08	7.45E-09	7.45E-09
0.4	0.000141	1.8E-05	6.58E-06	1.3E-05	1.71E-06	6.14E-07	2.56E-06	9.21E-07	9.21E-07
0.6	0.001176	0.00028	0.000138	0.00028	6.63E-05	3.25E-05	9.94E-05	4.87E-05	4.87E-05
0.8	0.006416	0.00259	0.001651	0.0033	0.001347	0.000861	0.00202	0.001292	0.001291
1	0.023659	0.01446	0.011433	0.02287	0.014489	0.011593	0.021734	0.017389	0.017218
1.2	0.060606	0.04878	0.044444	0.08889	0.075472	0.070175	0.113208	0.105263	0.098361
1.4	0.114746	0.10594	0.102985	0.20597	0.197648	0.194706	0.296472	0.292059	0.28851
1.6	0.175361	0.17075	0.169481	0.33896	0.336024	0.335197	0.504036	0.502796	0.501938
1.8	0.233878	0.23185	0.231407	0.46281	0.461984	0.461802	0.692976	0.692703	0.692542
2	0.286843	0.28601	0.285864	0.57173	0.571506	0.571468	0.857259	0.857202	0.857173

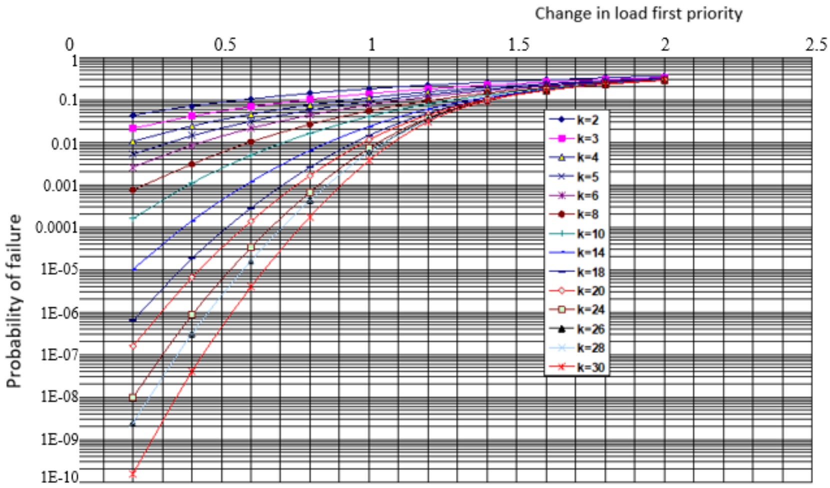


Fig. 3. Probability of denial of service for requests second priority ($N = 1; s = 2;\ \rho_2 = 0.8$)

Table 2. The results of calculating the probability of denial of service for requests of the second priority with different numbers of N, s and k ($\rho_2 = 0.8$)

	Probability of denial – P2m								
	N = 1			N = 2			N = 3		
	s = 2	s = 3	s = 4	s = 2	s = 3	s = 4	s = 2	s = 3	s = 4
	k = 20	k = 6	k = 3	k = 24	k = 8	k = 5	k = 26	k = 10	k = 5
0.2	1.59E-07	8.31E-05	0.000239	1.99E-08	0.00002	2.99E-05	7.45E-09	3.08E-06	4.48E-05
0.4	6.58E-06	3.50E-04	0.0007	1.71E-06	0.00011	1.26E-04	9.21E-07	2.66E-05	1.89E-04
0.6	0.000138	1.11E-03	0.001682	6.63E-05	0.00048	4.12E-04	4.87E-05	1.58E-04	6.18E-04
0.8	0.001651	2.95E-03	0.003491	0.001347	0.00168	1.11E-03	0.001292	7.20E-04	1.67E-03
1	0.011433	6.68E-03	0.006476	0.014489	0.00478	2.61E-03	0.017389	2.58E-03	3.92E-03
1.2	0.044444	1.33E-02	0.010989	0.075472	0.0117	5.45E-03	0.105263	7.74E-03	8.17E-03
1.4	0.102985	2.40E-02	0.01734	0.197648	0.025	1.03E-02	0.292059	1.99E-02	1.55E-02
1.6	0.169481	3.93E-02	0.025759	0.336024	0.0476	1.81E-02	0.502796	4.41E-02	2.71E-02
1.8	0.231407	5.94E-02	0.036367	0.461984	0.0815	2.96E-02	0.692703	8.61E-02	4.44E-02
1.9	0.285864	8.41E-02	0.049169	0.571506	0.127	4.55E-02	0.857202	1.49E-01	6.83E-02

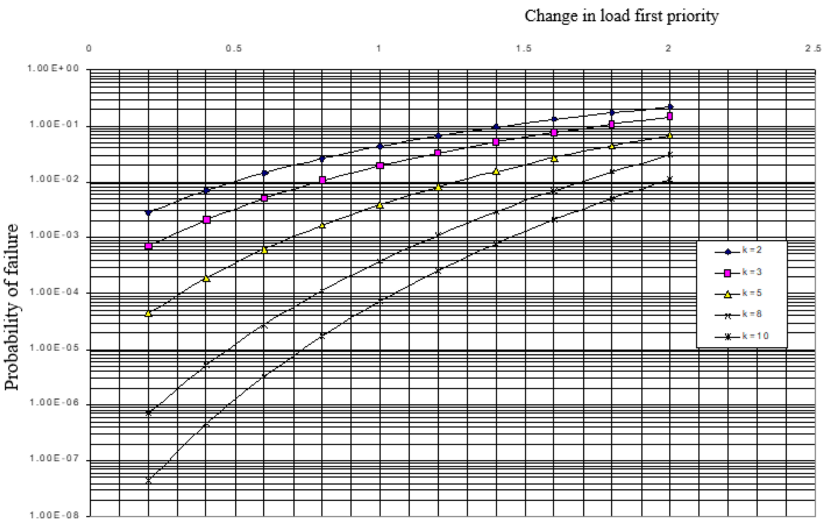


Fig. 4. Denial of service probability for second priority requests ($N = 3; s = 4; \rho_2 = 0.8$)

Table 1 shows the results of calculating the probability of denial of service for requests of the second priority (P2m) with a different number of waiting places (k). Number of nodes – N = 1. $-\rho_2 = 0.8$ second priority load, $-s = 2$ number of parallel channels. Table 1 shows the results of calculating the probability of denial of service for the requirements of the second priority (P_{2m}) with a different number of switching nodes (N) and waiting places (k). $-\rho_2 = 0.8$ is the load of the second priority, $-S = 4$ is the number of parallel channels.

In Fig. 3. the results of calculations of the probability of denial of service for requests of the second priority (P_{2m}) with a different number of waiting places (k) are given. The number of nodes $-N = 3$, $-\rho_2 = 0.8$ the load of the second priority and $-S = 4$ the number of parallel channels.

Table 2 shows the results of calculating the probability of denial of service for requests of the first and second priorities with a different number of switching nodes (N), parallel channels (s) and waiting places (k). Second priority load $-\rho_2 = 0.8$. The results of calculating the probability of denial of service for requests of the second priority ($-\rho_2 = 0.8$) in a multi-channel multi-node computer network with a different number of waiting places and different load of the first priority (= 0.1–2).

3. Conclusion

An algorithm has been developed for determining the probability of failure in multichannel and multinode networks for requests of the first and second priority due to a limited queue in service. Numerical calculations of the probability of denial of service for requests of the first and second priorities are given. It can be seen from the obtained characteristics and tables that in order to ensure the required QoS value, it is necessary to provide the required number of parallel serving channels between specific network nodes, as well as to determine the optimal number of waiting places (accumulator capacity) in its corresponding switching nodes.

References

[1] Amato V.: Fundamentals of network organization Cisco. 2, 2018.

[2] Baklanov I.G. NGN: Principles of construction and organization. Eco-Trendz, Moscow 2008.

[3] Black U. D.: Computer networks: Protocols, standards and interfaces. Moscow 2019.

[4] Bondarik Andreev D. V., Tarasov D. V., Kucheryavyy A. E.: Model networks for testing technical means of communication networks of the next generation. Recommendation MCE-T Q.3900, 2013.

[5] Bulgakov N. N., Miroshnikov V. I., Shibanov V. S.: Multi-channel system with limited queue and absolute priority, 2022.

[6] Guseynov Z. N.: Optimization of characteristics of computer networks. Proceedings of AzTU, Baku, 3, 2006, 29–32.

[7] Huseynov Z. N, Mammadov M. I, Ismayilov T. A.: Modeling and optimization of a computer corporate network with priority service "Seçkilər". II international scientific conference "Challenge and problems of modern science", London 2022, 138–142.

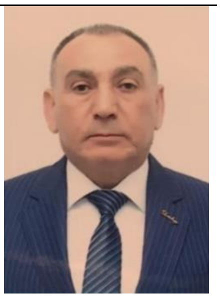
[8] Huseynov Z. N: Optimization of the Characteristics of single-chanel and multi-node computer networks providing priority services. German International Journal of Modern Science 30, 2022, 51–57.

[9] Vishnevsky V. M.: Theoretical foundations of designing computer networks. Technosfera, Moscow 2003.

Ph.D. Zakir Nasib Huseynov
e-mail: huseynov.z.n@mail.ru

Zakir Huseynov was born 2 July 1955. In 1980 graduated from Kirovabad State Pedagogical Institute after named H. Zardabi, Mathematic Faculty. By the decree of the President of the Republic of Azerbaijan dated 03.10.2006, he was awarded the honorary title "Honored Teacher of the Republic". In 2012 he defended his dissertation on "Research of performance indicators of priority service telecommunication networks" and received the degree of Doctor of Philosophy in Technique. From november 2020 he is the head of the Information Technologies department of Azerbaijan State Agricultural University.

http://orcid.org/0000-0003-3828-091X



Ph.D. Mahil Isa Mammadov
e-mail: mahilmi@mail.ru

Mahil Mammadov was born 1 May 1966. In 1990 graduated from the Azerbaijan Polytechnic Institute (now ATU), Electronic Computing Machines. On September 20, 2013, he defended dissertation on "Improvement of technology for the preparation of feed grains with information-software" for the Ph.D. degree in Engineering in the specialty "3102.01-Agroengineering"

http://orcid.org/0000-0002-9384-2746

M.Sc. Togrul Atabay Ismayilov
e-mail: ismayilovtogrul26@gmail.com

Togrul Ismayilov was born 16 March 1992. In 2015 graduated from Ganja State University. In 2019 graduated from the Azerbaijan State Oil and Industrial University, Information Technologies. From 2020 is working at the Azerbaijan State Agricultural University, Information Technologies department. In 2022 he started Ph.D. degree on Telecommunication Technologies at the Azerbaijan University of Technology. His research area is "Study of the effectiveness of telecommunication systems based on the architectural concept of next-generation communication networks".

http://orcid.org/0000-0002-2440-6385