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Research Article

Comparative Analysis of Economic Indicators of a Computer Corporate Network Servicing a Queue with Multiple Priorities

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ABSTRACT

The relevance of the work is confirmed by the fact that it was carried out in accordance with the design plan of the automated information system of the state institution and the management for the implementation of new equipment and modern technologies.

The proposed methods for calculating the probability of failures and the probability of timely delivery of request streams allow for determining the actual values of the quality indicators of the functioning of computer corporate networks.

Developed algorithmic programs in Python for analyzing the economic indicators of a computer corporate network with queue servicing based on multiple priorities, which allows for determining the most optimal design options for the computer corporate network.

Recommendations for the effective use of timely equipment in the creation of a corporate computer network,

proposed methods of calculation include a comparative analysis of economic indicators, a corporate computer network, and queue servicing with multiple priorities..

Keywords: comparative analysis, computer network, corporate, calculation, load, number, waiting places, priority, algorithm, program.

INTRODUCTION

Materials and methods

In this work, in addition to characterizing corporate computer networks, a comparative analysis of their performance indicators and economic efficiency according to one or several priorities based on the number of channels, nodes, and waiting places has been conducted.

The operation of the analytical model of a corporate computer network has been studied, and the probabilities of request loss and timely delivery have been determined. Analyses of corporate computer networks (telephone communications, digital networks with service integration, etc.) are well presented in works [5], [6].

The application of optimization methods in network planning can reduce project implementation costs by up to 20% [1], [4]. Stages of strategic, long-term, medium-term, and current planning are distinguished. Long-term (medium-term) planning determines the transition to a new communication network structure based on the criterion of minimizing total capital costs. According to the position of network optimization theory, networks are decomposed into structural and parametric optimization tasks. The first task is to select the optimal network structure considering requirements for its bandwidth, reliability, survivability, and types of computer equipment used. The second task is based on the development of mathematical models of the network and its elements, optimizing channel distribution.

At present, multi-channel QS of the M/M/S type with failures are used to model computer corporate networks. To describe the stationary mode of operation of such QS, the Erlang distribution is used, and the quality of service indicator is the probability of losing requests [8], [9]:

$$P_j = \frac{{\rho_j}^{s_j}}{s_j!}\left(\sum_{n=0}^{s_j}\frac{{\rho_j}^n}{n!}\right)^{-1}, \qquad (1)$$

where $\rho_j = \frac{\lambda_j}{\mu}$ – is the intensity of the load entering the j –communication path;

λ_j- the intensity of the incoming flow in the j –communication path;

μ –service intensity;

s_j - the number of channels in the QS that characterizes the j- communication path.

The results of calculations by formula (1) are shown in **Fig.1.** As can be seen from **Fig. 1.** based on the choice of requirements for the quality of service of requests (P_j) and on the basis of load planning (ρ_j), you can choose the number of parallel channels.

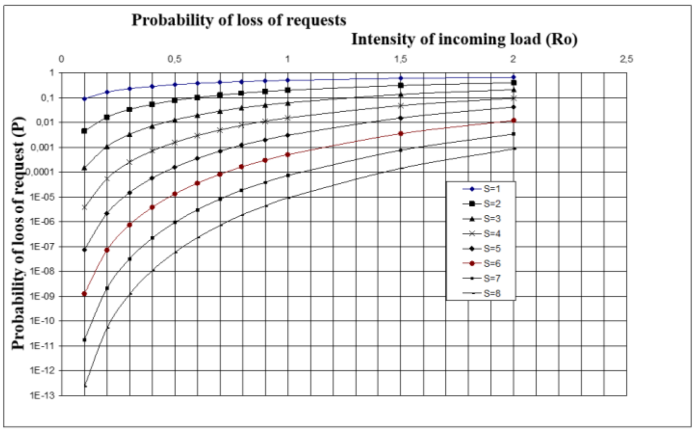

Fig.1. Dependence of the probability of loss of requests (P_j) on the change in the incoming load in the j – communication path (ρ_j)and on the number of parallel channels(s_j)

An integral characteristic of the quality of service for requests in the communication paths of computer corporate networks is the probability of timely delivery of messages, which is determined by the expression:

An integral characteristic of the quality of service for requests in the communication paths of computer corporate networks is the probability of timely delivery of messages, which is determined by the expression [16,17]:

$$Q_j = \frac{\bar{\mu}}{\bar{\mu}+c_j}\frac{\bar{\eta}}{\bar{\mu}+\nu}(1-\tilde{P}_j), \qquad (2)$$

where $\bar{\mu}$ –is the average service intensity;

c_j –failure rate;

$$\gamma = \frac{1}{T_j};$$

T_j - allowable average delay time;

$\frac{\bar{\mu}}{\bar{\mu}+c_j}$ –the probability that during the transmission of the message the j –communication path will not fail;

$\frac{\bar{\mu}}{\bar{\mu}+\gamma}$ – the probability that the message will not lose value;

$\tilde{P}_j$ –is the stationary probability of loss of requests in the$j$ –M communication path with unreliable serving devices (OS).

Consider a link with a bandwidth of 19.2 Kbps, an average traffic of 14 packets per second ($\lambda = 14$) and an average packet size of 800 bits. Packet service rate - packet/s. The throughput of such a link is 24 packets per second, so the delay in this link is $T_j = 1/(\mu - \lambda) = 1/(24 - 14) = 100$ ms. Taking into account the above data, according to formula (2), dependences of the change in the quality of service (Q_j) on the stationary probability of request losses ($\tilde{P}_j$) for different values of the failure rate (c_j) **Fig. 2** are constructed. As can be seen from the characteristics obtained, the failure rate (cj) has little effect on changes in the quality of service (Q_j).

RESULTS AND DISCUSSIONS

The results obtained from this work were used in the design, development, and operation of the corporate computer network of the largest government institutions.

Fig.3. According to the established information transmission structure, it is carried out on three levels:

- In the information center of the central base institution.
- In the information center of the autonomous institution.
- In the information section of the district institution.

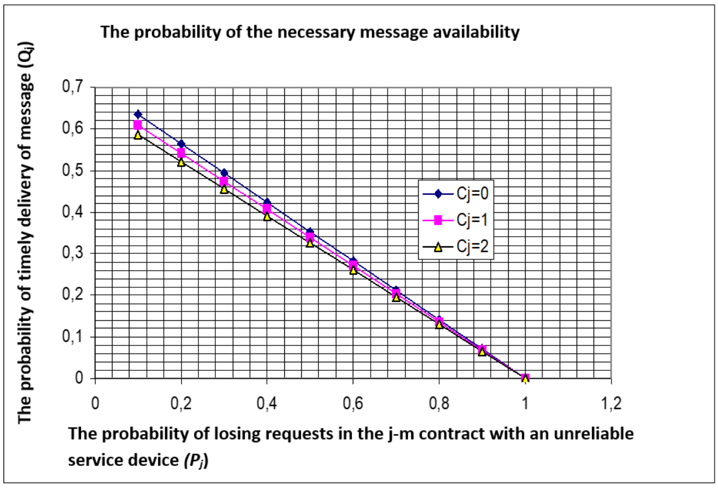

Fig.2. Dependence of quality of service on the probability of loss of requests

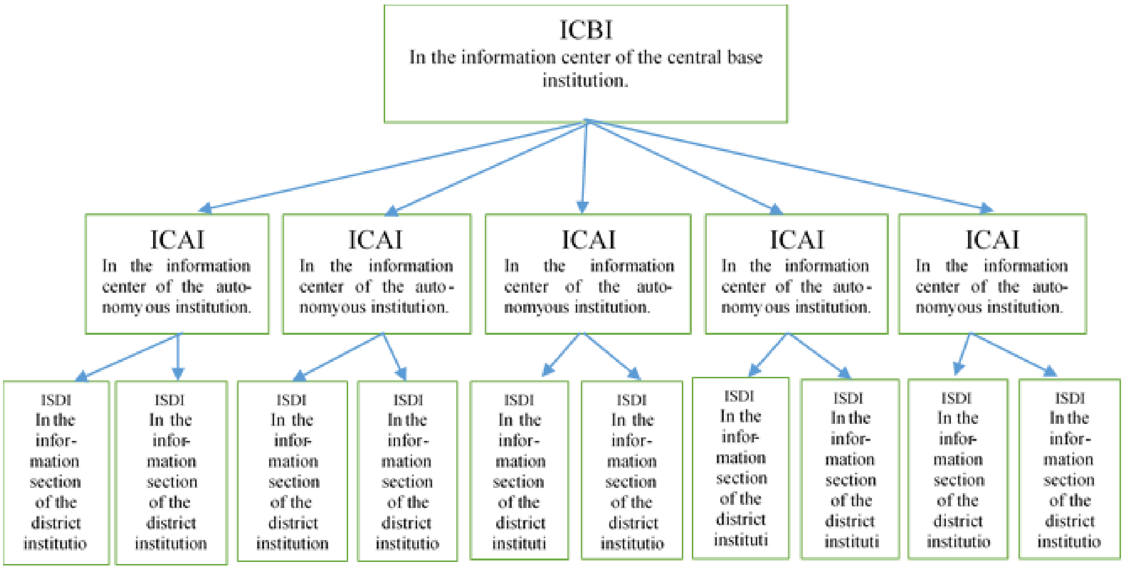

Fig.3. Structural diagram of the information center of the central base institution.

The organization needs to be provided with modern computer equipment, a webcam, telecommunications equipment, and a special screen.

When selecting optimal parameters for switching nodes in a computer corporate network operating under a limited queue system with a Poisson incoming request flow, we use the loss cost function in the system based on economic indicators, which has the following form

[2, 3, 6,12]:

$$G(s) = \left[q_{cd}(s - M_{cbs}) + q_{anr}.M_{anr} + q_y.W_{(s+k)}.\lambda + q_k.M_{cbs}\right].T \quad (3)$$

where the $W_{(s+k)}$ – probability that all s channels and k waiting places are occupied by service;

M_{anr} –average number of requests in the queue;

M_{cbs} –caverage number of channels occupied by servicing;

λ – intensity of the incoming request stream;

q_{cd} – the cost per unit of channel downtime;

q_{anr} – the cost of losses associated with requests idling in the queue over time;

q_k – the cost of operating each channel per unit of time;

T – calculation time interval.

In expression (1), the parameters , $W_{(s+k)}$, M_{anr}, M_{cbs} , for a switching node operating under a limited queue system are determined as a function of the distribution of the number (mass service system MSS),of requests in a combined system (loss/waiting) [2]:

$$W_{(s+k)} = \frac{\rho^{s+k}}{s^k s!} \cdot W_O; \quad (4)$$

$$M_{anr} = \sum_{j=1}^{k} jW_{(s+k)}; \quad (5)$$

$$M_{cbs} = \sum_{j=1}^{s} jW_j, \quad (6)$$

where ρ – the intensity of the incoming load;

s – number of channels;

k – maximum number of waiting spots in the queue.

Let's consider a numerical example of optimizing the number of channels and the minimum cost for different load values. A program was developed to solve the problem using expressions (4) – (6), implemented with **the Excel 2019** program, and a program was also created in the **Python** algorithmic language, which is provided in **Appendix 1**.**Optimization program comparative analysis of economic indicators of a corporate computer network servicing a queue with multiple priorities**

Appendix 1

zakir.py - D:/pyutonkurs/zakir.py (3.13.1)

File Edit Format Run Options Window Help

```python
import math
def optpar():
    qnk = 0.445
    qoj = 7.42E-04
    qy = 0.004
    qk = 2.17E-05
    ly = 1.4
    t = 1
    s = int(input("Enter s: "))
    k = int(input("Enter k: "))
    ron = float(input("Enter ron: "))
    rok = float(input("Enter rok: "))
    dro = float(input("Enter dro: "))
    n = int((rok - ron) / dro) + 1  # Integer division and +1
    ro = ron
    for i in range(n):
        f = 1
        for j in range(1, s + 1):  # Python range is exclusive of the end
            f *= j
        p = 1
        h = 1
        j = 1
        while j <= s:
            h = h * ro / j
            p = p + h
            j = j + 1
        p = p + (math.exp(j * math.log(ro))) / f

        q = 0
        for j in range(s + 1, s + k + 1):
            q += (math.exp(j * math.log(ro))) / (f * math.exp((j - s) * math.log(s)))
        w0 = 1 / (p + q)
        for j in range(0, s + 2):
            if j > s:
                wj = w0 * math.exp(j * math.log(ro)) / (f * math.exp((j - s) * math.log(s)))
            elif 0 < j <= s:  # Combined condition
                wj = w0 * math.exp(j * math.log(ro)) / f
        mzan = 0 for j in range(1, s + 1):
            mzan += j * wj
        wsk = math.exp((s + k) * math.log(ro)) / (math.exp(k * math.log(s)) * f) * w0
        moj = 0
        for j in range(1, k + 1):
            moj += j * wsk
        gs = (qnk * (s - mzan) + qoj * moj + qy * wsk * ly + qk * mzan) * t
        print(f"ro={ro:.1f}     gs={gs:.6f}") #Formatted output
        ro += dro
optpar()
```

Ln: 38 Col: 0

Key Changes and Explanations for Python Conversion:

1. Input: Python uses input() to get user input. We convert the input to the appropriate data type (int or float).
2. Range: Python's range() function is exclusive of the end value. So, range(1, s + 1) is used instead of for j := 1 to s do.
3. Looping: The repeat...until loop is replaced with a while loop.
4. Math Functions: Pascal's exp() and ln() are replaced with Python's math.exp() and math.log(). You need to import math to use these.
5. Integer Division: The trunc() function is implicitly handled by Python's integer division when you divide two integers. If you want to ensure integer division, use //. In this case, int((rok - ron) / dro) is already doing what trunc did in Pascal.
6. Combined Condition: The Pascal (0 < j) and (j <= s) can be directly written as 0 < j <= s in Python.
7. Formatted Output: Python's f-strings provide an elegant way to format the output, similar to Pascal's formatting specifiers. f"ro={ro:.1f} gs={gs:.6f}" formats ro to one decimal place and gs to six decimal places.
8. Comments: I've added comments to explain some of the changes and the logic.

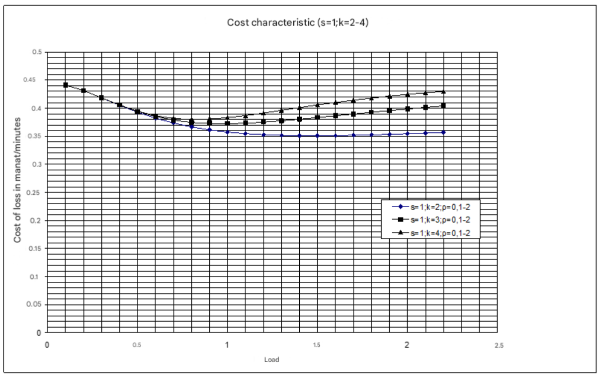

Fig. 4. Dependence of cost on load changes with the number of channels s=1 for different numbers of waiting places (k=2-4)

From Figure 4 and Appendix Table 1, it can be seen that with single-channel service (s=1), the minimum values of loss costs decrease with the increase in the number of waiting places (k) and are accordingly equal to:

The cost of the channel due to load changes with the number of channels s=1 for different numbers of waiting places (k=2-4)

Table 1

Cost in manats/minutes			
Number of channels s=1			
Load	Number of waiting spots (k)		
ρ	2	3	4
0,1	0.4410	0.4410	0.4410
0,2	0.4312	0.4312	0.4312
0,3	0.4186	0.4186	0.4186
0,4	0.4054	0.4058	0.4060
0,5	0.3931	0.3944	0.3950
0,6	0.3825	0.3854	0.3870
0,7	0.3738	0.3789	0.3821
0,8	0.3668	0.3749	0.3802
0,9	0.3615	0.3729	0.3808
1	0.3576	0.3725	0.3833
1,1	0.3548	0.3734	0.3870
1,2	0.3529	0.3752	0.3915
1,3	0.3517	0.3776	0.3963
1,4	0.3511	0.3804	0.4011
1,5	0.3510	0.3834	0.4058
1,6	0.3513	0.3866	0.4103
1,7	0.3519	0.3897	0.4144
1,8	0.3526	0.3928	0.4181
1,9	0.3536	0.3958	0.4216
2	0.3546	0.3987	0.4247

The results of optimizing the cost characteristic from load changes with different numbers of channels for various numbers of waiting areas are presented in Figures 4-5

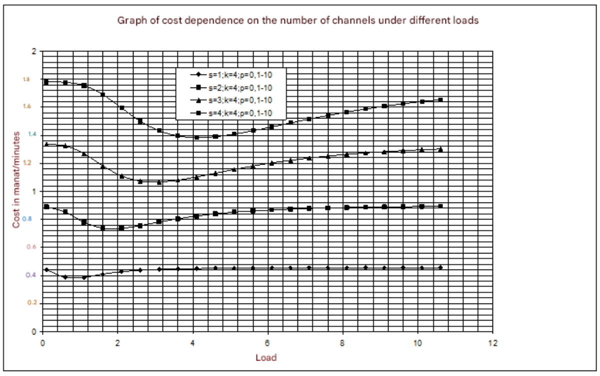

Fig. 5. Dependence of loss cost on load changes with different numbers of channels (s=1-4) for waiting spots k=4

Cost of losses from load changes with the number of channels s=1-4 for the number of waiting places k=4

Table 2

Cost of losses in manat/minutes				
Number of waiting places k=4				
Load ρ	**Number of channels s=1-4**			
	1	**2**	**3**	**4**
0.1	0.4410	0.8897	1.3350	1.7800
0.6	0.3870	0.8533	1.3246	1.7780
1.1	0.3870	0.7803	1.2691	1.7557
1.6	0.4103	0.7380	1.1826	1.6908
2.1	0.4274	0.7366	1.1105	1.5943
2.6	0.4377	0.7564	1.0734	1.5002
3.1	0.4437	0.7816	1.0670	1.4324
3.6	0.4475	0.8051	1.0802	1.3954
4.1	0.4499	0.8244	1.1033	1.3839
4.6	0.4516	0.8398	1.1300	1.3905
5.1	0.4527	0.8517	1.1565	1.4085
5.6	0.4536	0.8609	1.1811	1.4329
6.1	0.4542	0.8681	1.2030	1.4603
6.6	0.4547	0.8738	1.2221	1.4885
7.1	0.4551	0.8783	1.2385	1.5159
7.6	0.4554	0.8819	1.2525	1.5419
8.1	0.4557	0.8848	1.2645	1.5659
8.6	0.4559	0.8872	1.2746	1.5879
9.1	0.4561	0.8891	1.2833	1.6077
9.6	0.4562	0.8907	1.2907	1.6255
10.1	0.4563	0.8921	1.2971	1.6415
10.6	0.4564	0.8933	1.3025	1.6557

The proposed method and numerical example of optimizing the parameters of a switching node, operating under multiple priorities in a corporate computer network, demonstrate the possibility of selecting the optimal design variant.

As the initial data, the regulatory data for 2024 were used [18] (on October 1, 2021, the Ministry of Transport, Communications and High Technologies was renamed the Ministry of Digital Development and Transport.) Ministry of Digital Development and Transport of the Republic of Azerbaijan.

Let's say:

Note: 1 USD = 1.7 manat

- $q_{cd} = 0{,}445$ manat per minute= 0,26 USD per minute;
- $q_{anr} = 7{,}42.10^{-4}$ manat per minute= 4,36.10-4 USD per minut;
- $q_y = 0{,}004$ manat per minute= 0,00235 USD per minute;
- $\lambda = 25$ packets/s.

The cost of operating each channel per month is 0.937 manat=0,55 USD.

- $q_{\kappa} = \frac{0{,}937}{30.24.60} = 2{,}17.10^{-5}$ manat per minute=1,276.10-5 USD per minute
- The average packet length is 144 bytes = 144.8 = 1151 bits;
- The line speed is 64000 bps.
- The average service time for each package is seconds $T_s = \frac{1152}{64000} = 0{,}018$ c.
- $\rho = \lambda.T_s = 25.0{,}018 = 0{,}75$. Calculations are performed for various load values (ρ).

The results of optimizing the cost characteristic from load changes with different numbers of channels for various numbers of waiting areas are presented in Figures 4-5.

From Figure 4 and Appendix Table 1, it can be seen that with single-channel service (s=1), the minimum values of loss costs decrease with the increase in the number of waiting places (k) and are accordingly equal to:

- when k=2 and ρ=1,5 G_{min}=0,3510 manat per minute=0,206 USD per minute
- when k=3 and ρ=1,0 G_{min}=0.3725 manat per minute=0,22 USD per minute
- when k=4 and ρ=0,8 G_{min}=0.3802 manat per minute=0,2236 USD per minute.

From Figure 5 and Appendix Table 2, show the dependences of the cost of losses for a different number of channels (s=1-4) and a certain number of waiting places (k=4).

- when k=2 and ρ=7,1 G_{min}=1,2137 manat per minute=0,714 USD per minute;
- when k=3 and ρ=5,1 G_{min}=1,3291 manat per minute=0,782 USD per minute;
- when k=4 and ρ=4,1 G_{min}=1,3839 manat per minute=0,814 USD per minute;
- when k=5 and ρ=3,6 G_{min}=1,4162 manat per minute=0,833 USD per minute.

In Figure 4-5 and Table 1-2, the dependencies of loss costs for different numbers of channels (s=1-4) and a certain number of waiting places (k=4) are presented.

CONCLUSION

Based on the developed models, optimization methods, and the presented results of numerical calculations on a PC, the following conclusions can be drawn.

The proposed method and numerical example of optimizing the parameters of the switching node and service system demonstrate the possibility of selecting the optimal design option.

It has been shown that in a corporate network, the probability of request loss (P_j) depends on the intensity of the incoming load in the j -th communication channel and the number of parallel channels (s_j). The intensity of failure occurrences (c_j)has a negligible impact on changes in service quality (Q_j)due to the presence of parallel channels.

From the presented results, it can be concluded that when designing switching nodes, the analysis of economic indicators of a corporate computer network with queue servicing by multiple priorities, to optimize the number of channels and the number of waiting places, it is necessary to consider the found minimum loss cost values for optimal load values and the number of waiting places.

Discussion: The discussion of results and their comparison with the conclusions of other researchers plays an undeniable role in advancing scientific knowledge and understanding the complex issues of corporate computer network performance. By analyzing the data obtained in previous sections and comparing it with the findings of other researchers, it is possible to identify common patterns, key differences, and additional aspects of this problem. The research problem lies in finding optimal solutions to ensure the efficient operation of corporate computer networks under various loads and traffic conditions. The increase in the number of users, 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 network user service.

The reference book by Bessler R., Deutsch A. is dedicated to the design of communication networks. The book presents an extensive amount of material on methods for optimal design of communication networks [1].

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].

Z. Huseynov, T. Ismayılov, S. Babayeva, S. Baratzade, N. Baratzade. Development of an Analytıcal model and Optımısatıon of computer networks wıth a queue prıorıty to one server In this research work, the possible maximum information transfer rate in a client-server architecture computer network with prioritized requests to a single server was mathematically calculated and examined. Mathematical models were constructed, formulas describing the dependencies of variables on each other and their impact on the result were derived, and graphs were created based on them. The network's efficiency was determined under various loads based on the obtained data [3].

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 distinguishing feature of modern computer networks, according to Huseynov.Z.N., Muradov P.C., Suleymanov A.S [6], is the delivery of various types of information packets to their destination via different routes. The main objective of this study is to determine the relationship between packet loss and network loads and resources. Mathematical models are proposed to calculate the probability of service failures in multi-channel single-node and multi-channel multi-node networks with limited queues and absolute priority.

R. Ghimire and R. Noor [7] 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 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 [8].

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.

The document [10] 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.

S. Prakash explored the possibility of using cloud technologies to optimise the performance of communication networks [11]. 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.

Z. N. Huseynov, M. N. Mammadov, A. Q. Masimov, S. Baratzade, N. A. Masimli in this article showed that to ensure the necessary level of service quality for requests, it is necessary to increase the number of waiting places at individual network nodes. 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[12].

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 main purpose of the study by R. de Moraes and F. Vasques [16] 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 evaluation of various communication methodologies on the quality of service offered to a particular management application and the impact of communication parameters on management stability. The document also highlights the problems of implementing control systems in distributed, asynchronous network environments and building reliable systems from unreliable components. 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 [17] is devoted to the theory of multiclass queues and its application in the analysis of the performance of computer systems. The paper presents the results of analytical studies, and examples of the use of these results in real systems. Models of multiclass queues are described, which allow analysing computer systems with different types of resources and transactions. The paper also discusses the limitations and problems associated with the use of 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 various parameters on the effectiveness of communication networks. It is important to note 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.

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