Comparative analysis of the efficiency of economic indicators of a combined system of modern telecommunication networks with limited queuing, with single and multiple priorities.

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Annotation

This article analyzes the economic efficiency of the performance indicators of a combined system of modern telecommunication networks with a limited queue, with one and multiple priorities.

To determine the service rate for optimizing the number of channels and waiting places, it is necessary to calculate the minimum values of the cost loss functions, which depend on specific load values.

The numerical calculations and the graphs of the dependence constructed make it possible to determine the required quality of modern telecommunication networks operating on a combined system with a given number of nodes, the number of waiting places in specific nodes, and the values of first and second priority loads.

Developed algorithmic programs in Python for calculating the optimization of parameters for a switching node operating under a combined service system allow us to determine the most optimal design options and optimal parameters for switching nodes operating in a system with a limited queue and a Poisson distribution of incoming requests. We use a cost function for losses in the system based on the economic indicators of modern telecommunications networks.

Keywords: computer network, calculation, load, quantity, waiting places, priority, algorithm, switching devices.

Materials and Methods

The aim of the work is to develop methods for determining the quality characteristics of indicators for combined modern telecommunication networks with priority service, aimed at improving their efficiency and the quality of communication service provision. The main tasks here are:

- a systematic analysis of the current state of the problem and development trends of modern telecommunication networks, and the identification of the main tasks, the solution of which significantly affects the efficiency [2] of their functioning and development;
- development of methods for calculating the quality indicators of the functioning of the combined system of modern telecommunication networks with priority service for incoming packet flows;
- development of algorithmic programs in Python for calculating the optimal values of the quality characteristics of the functioning indicators of a combined system of modern telecommunication networks with priority service and a limited queue.
- development of methods for optimizing the parameters of a switching node operating under a combined service system.

When choosing the optimal parameters for switching nodes operating under a limited queue system with a Poisson arrival process, we use the system loss cost function from [1] as an economic indicator, which has the following form [5]:

$$G(s) = \left[q_{cd}(s - M_{cbs}) + q_{anr}.\mathrm{M}_{anr} + q_{\mathrm{y}}.W_{(s+k)}.\lambda + q_k.M_{cbs}\right].T \quad (1)$$

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.

$$W_0 = \left[\sum_{j=0}^{s}\frac{\rho^j}{j!} + \sum_{j=(s+1)}^{j=(s+k)}\frac{\rho^j}{s!\,s^{(j-s)}}\right]^{-1}; \quad (2)$$

$$W_j = \begin{cases} \frac{\rho^j}{j!} W_0, 0 \le j \le s; \\ \frac{\rho^j}{s! s^{(j-s)}} W_0, j > s; \end{cases} \tag{3}$$

$$W_{(s+k)} = \frac{\rho^{s+k}}{s^k s!} \cdot W_0; \tag{4}$$

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

$$M_{cbs} = \sum_{j=1}^{s} j W_j, \tag{6}$$

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. The developed algorithmic program in **Python** for solving the problem expressed by equations (2) - (6) is shown in **Programs.1.**

A program for optimizing the cost characteristics of a switching node operating under a combined service system

```
import math

# Cost Constants
Q_NK = 0.445 # Server downtime cost
 Q_OJ = 7.42E-04 # Queue maintenance cost
Q_Y = 0.004 # Failure damage cost
 Q_K = 2.17E-05 # Operating cost
L_Y = 1.4 # Failure losses
 T = 1 # Time interval

# Input system parameters
s = int(input("Enter the number of servers (s): "))
 k = int(input("Enter the maximum queue length (k): "))
ron = float(input("Enter the initial value of ρ: "))
rok = float(input("Enter the final value of ρ: "))
 dro = float(input("Enter the step size for changing ρ: "))

# Calculate the number of iterations
 n = int((rok - ron) / dro) + 1
 ro = ron

for _ in range(n):
 # 1. Calculating the factorial of servers
```

```
f = math. factorial(s) # Optimized factorial calculation

# 2. Probability calculation for states without a queue
 (0 <= j <= s) p = sum(ro**j / math.factorial(j) for j in range(s + 1))

# 3. Probability calculation for states with a queue (s+1 <= j <= s+k)
q = sum(ro**j / (f * s**(j - s)) for j in range(s + 1, s + k + 1))

# 4. Normalization constant w0 = 1 / (p + q)

# 5. Calculate all probabilities Wj and save them in a list
 wj_list = []
for j in range(s + k + 1):
 if j <= s:
# Probabilities for states without a queue
wj = w0 * (ro**j) / math.factorial(j)
 else:
#Probabilities for states with a queue
 wj = w0 * (ro**j) / (f * s**(j - s))
 wj_list.append(wj)
# 6. Calculation of the average number of busy servers
m_zan = sum(j * wj_list[j] for j in range(1, s + 1))

# 7. Calculation of the average queue length (CORRECTED FORMULA)
 m_och = sum((j - s) * wj_list[j] for j in range(s + 1, s + k + 1))

# 8. Probability of failure (last state)
w_sk = wj_list[s + k]

# 9. Calculation of the overall effectiveness indicator
 G_S = (Q_NK * (s - m_zan) +
Q_OJ * m_och +
Q_Y * w_sk * L_Y +
Q_K * m_zan) * T

print(f'ρ={ro:3.1f} G_S={G_S:6.4f}')
ro += dro
```

Programs.1. Python programs for calculating the optimization of the number of channels and the number of waiting spaces.

Algorithmic programs for optimizing the number of channels in a switching node operating under a combined service system, just like for a switching node operating under a waiting system, involve sequentially calculating the value of the objective function G(s,k) for different values of the number of communication channels and the number of waiting places.

The dependencies of cost on load changes have been determined for different numbers of channels and different numbers of waiting places.

This software for optimizing the cost characteristics of a switching node operating under a combined service system (**Programs.1.**) was implemented using **Excel 2019**.

The 2024 regulatory data from [14] was used as the initial data. (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;
- λ = 25 packets/s.

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

- $q_к = \frac{0{,}937}{30.24.60} = 2{,}17.10^{-5}$ 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 for different numbers of channels and different numbers of waiting places are presented in Figures 1-5.

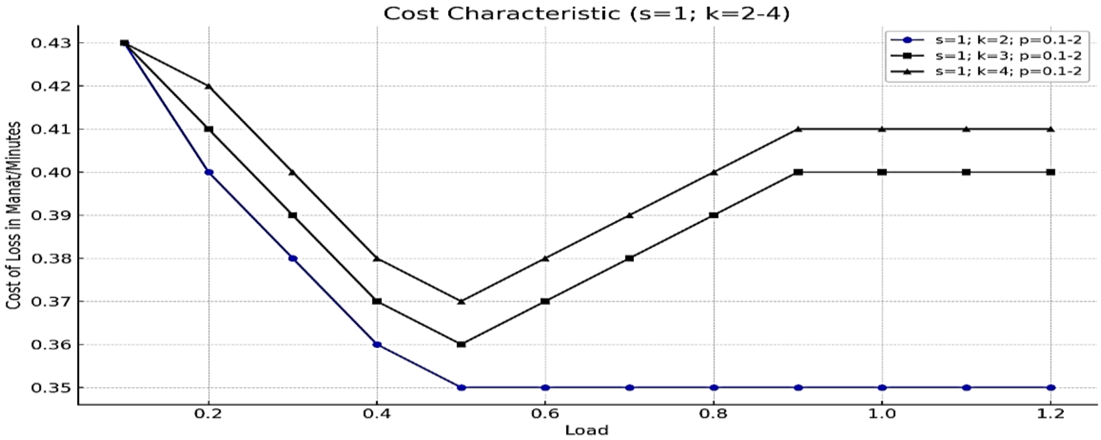

Fig. 1. Dependence of cost on load changes with the number of channels s=1 for different numbers of waiting places (k=2-4)

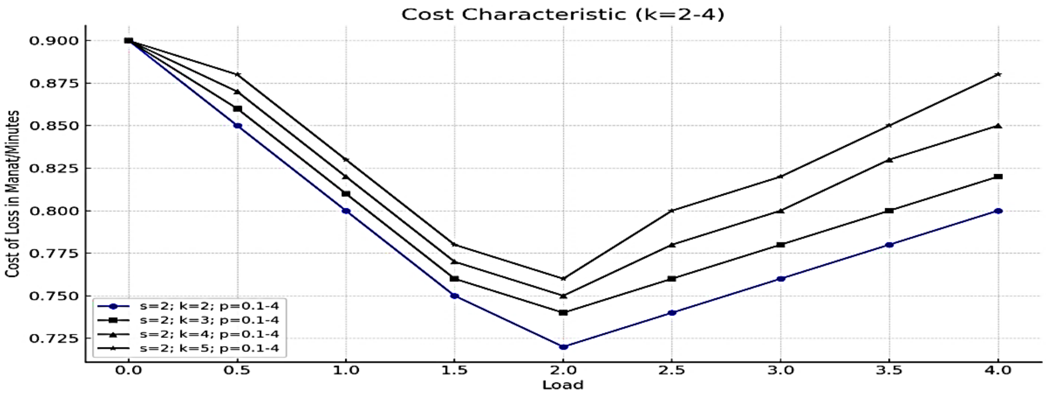

Fig. 2. Dependence of cost on load changes with the number of channels s=2 for different numbers of waiting places (k=2-5)

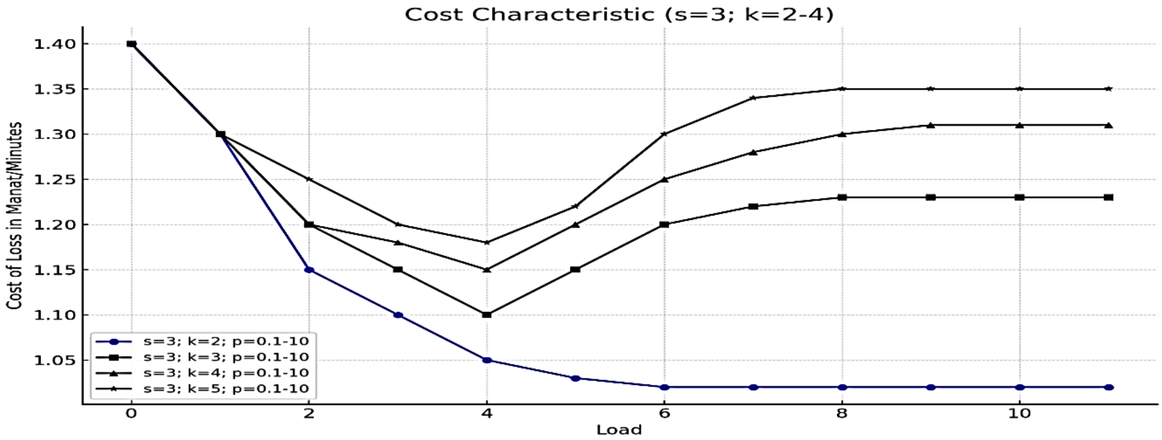

Fig. 3. Dependence of loss cost on load changes with the number of channels s=3 for different numbers of waiting places (k=2-5)

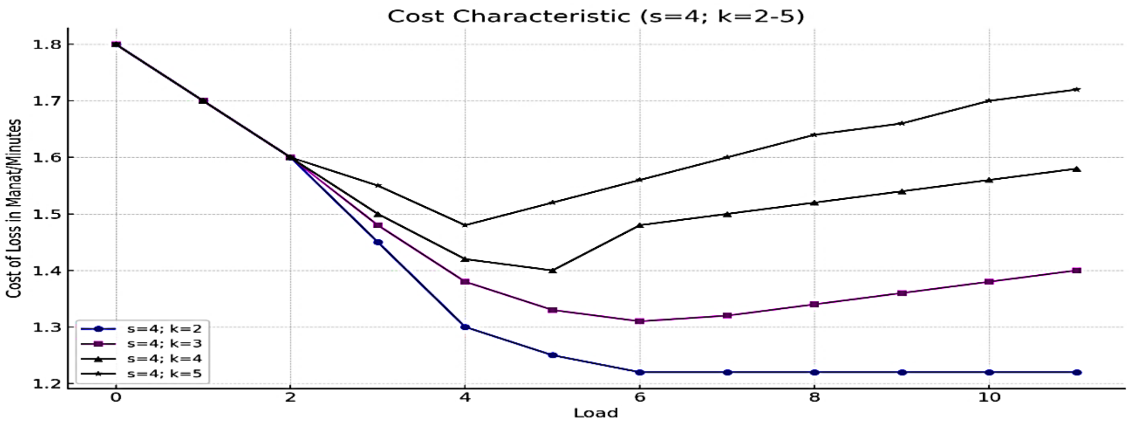

Fig. 4. Dependence of loss cost on load changes with the number of channels s=4 for different numbers of waiting places (k=2-5)

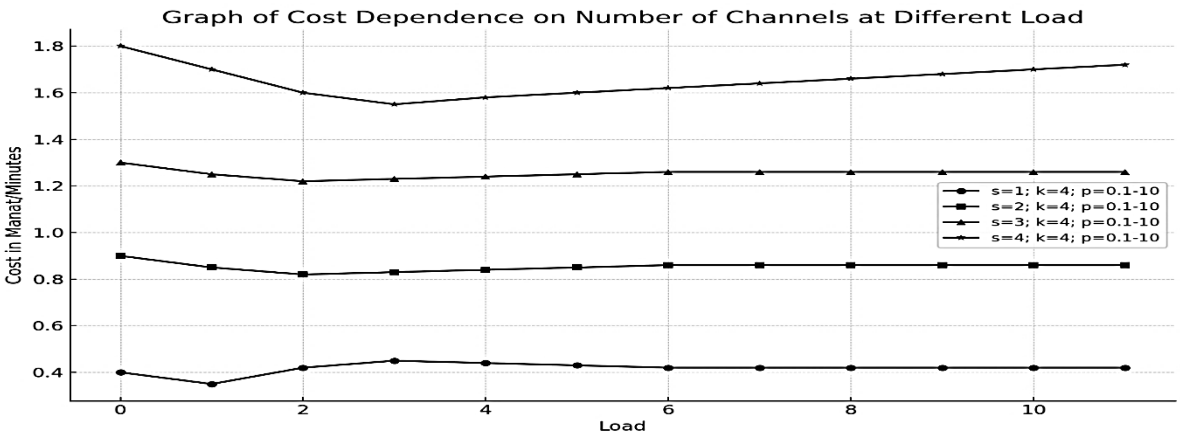

Fig. 5. Dependence of loss cost on load changes with different numbers of channels (s=1-4) for waiting spots k=4

The cost of the channel from 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**

From Figure 3 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=1,8 G_{min}=0.3526 manat per minute=0,207 USD per minute
- when k=2 and ρ=1,5 G_{min}=0,3510 manat per minute=0,206 USD per minute
- when k=2 and ρ=1 G_{min}=0.3576 manat per minute=0,210 USD per minute
- when k=3 and ρ=1,8 G_{min}=0.3927 manat per minute=0,231 USD per minute
- when k=3 and ρ=1,5 G_{min}=0.3834 manat per minute=0,225 USD per minute
- when k=3 and ρ=1,0 G_{min}=0.3725 manat per minute=0,220 USD per minute
- when k=4 and ρ=1,8 G_{min}=0.4181 manat per minute=0,246 USD per minute
- when k=4 and ρ=1,5 G_{min}=0.4058 manat per minute=0,239 USD per minute
- when k=4 and ρ=1 G_{min}=0.3833 manat per minute=0,225 USD per minut

The cost of the channel from changes in load with the number of channels s=2 for various numbers of waiting areas (k=2-6)

Table 2

Cost of the channel in manats/minutes				
Number of channels s=2				
Loaded	**Number of waiting spots (k)**			
ρ	**2**	**3**	**4**	**5**
0,1	**0.8897**	**0.8897**	**0.8897**	**0.8897**
0.5	**0.8659**	**0.8659**	**0.8659**	**0.8659**

0.9	**0.8073**	**0.8082**	**0.8086**	**0.8088**
1.1	**0.7761**	**0.7788**	**0.7803**	**0.7811**
1.3	**0.7482**	**0.7542**	**0.7578**	**0.7601**
1.5	**0.7248**	**0.7356**	**0.7428**	**0.7477**
2.1	**0.6808**	**0.7122**	**0.7366**	**0.7561**
2.3	**0.6728**	**0.7120**	**0.7430**	**0.7679**
2.7	**0.6633**	**0.7182**	**0.7613**	**0.7949**
2.9	**0.6610**	**0.7233**	**0.7715**	**0.8079**
3.1	**0.6598**	**0.7291**	**0.7816**	**0.8198**
3.3	**0.6595**	**0.7354**	**0.7914**	**0.8305**
3.5	**0.6599**	**0.7419**	**0.8007**	**0.8400**
3.7	**0.6608**	**0.7484**	**0.8093**	**0.8482**
3.9	**0.6622**	**0.7549**	**0.8172**	**0.8553**
4.1	**0.6639**	**0.7612**	**0.8244**	**0.8614**

From Figure 4 and Appendix Table 2, it can be seen that with two-channel service (s=2), the minimum loss cost values are:

- when k=2 and ρ=4,1 G_{min}=0.6639 manat per minute=0,391USD per minute
- when k=2 and ρ=1,5 G_{min}=0,7248 manat per minute=0,426 USD per minute
- when k=2 and ρ=1,1 G_{min}=0.7761 manat per minute=0,457 USD per minute
- when k=3 and ρ=4,1 G_{min}=0.7612 manat per minute=0,448 USD per minute
- when k=3 and ρ=1,5 G_{min}=0.7356 manat per minute=0,433USD per minute
- when k=3 and ρ=1,1 G_{min}=0.7788 manat per minute=0,458USD per minute
- when k=4 and ρ=4,1 G_{min}=0.8244 manat per minute=0,485 USD per minute
- when k=4 and ρ=1,5 G_{min}=0.7428 manat per minute=0,437 USD per minute
- when k=4 and ρ=1,1 G_{min}=0.7803 manat per minute=0,459USD per minute
- when k=5 and ρ=4,1 G_{min}=0.8614manat per minute=0,507 USD per minute
- when k=5 and ρ=1,5 G_{min}=0.7477manat per minute=0,440 USD per minute

when k=5 and ρ=1,1 G_{min}=0.7811 manat per minute=0,459 USD per minute

Cost of the channel from load changes with the number of channels s=3 for different numbers of waiting places (k=2-4)

Table 3

Cost of the channel in manat/minutes				
Number of channels s=3				
Load	**Number of waiting spots (k)**			
ρ	**2**	**3**	**4**	**5**
0.1	**1.3350**	**1.3350**	**1.3350**	**1.3350**
0.6	**1.3246**	**1.3246**	**1.3246**	**1.3246**
1.1	**1.2689**	**1.2691**	**1.2691**	**1.2692**
1.6	**1.1788**	**1.1813**	**1.1826**	**1.1832**
2.1	**1.0936**	**1.1038**	**1.1105**	**1.1149**
2.6	**1.0313**	**1.0554**	**1.0734**	**1.0872**
3.1	**0.9910**	**1.0330**	**1.0670**	**1.0951**
3.6	**0.9666**	**1.0284**	**1.0802**	**1.1235**
4.1	**0.9529**	**1.0346**	**1.1033**	**1.1593**
4.6	**0.9462**	**1.0470**	**1.1300**	**1.1943**
5.1	**0.9441**	**1.0624**	**1.1565**	**1.2248**
5.6	**0.9451**	**1.0791**	**1.1811**	**1.2498**
6.1	**0.9481**	**1.0959**	**1.2030**	**1.2697**
6.6	**0.9524**	**1.1124**	**1.2221**	**1.2853**
7.1	**0.9576**	**1.1280**	**1.2385**	**1.2975**
7.6	**0.9633**	**1.1427**	**1.2525**	**1.3071**

8.1	**0.9694**	**1.1564**	**1.2645**	**1.3146**
8.6	**0.9757**	**1.1690**	**1.2746**	**1.3206**
9.1	**0.9821**	**1.1807**	**1.2833**	**1.3253**
9.6	**0.9885**	**1.1914**	**1.2907**	**1.3291**
10.1	**0.9948**	**1.2012**	**1.2971**	**1.3322**
10.6	**1.0011**	**1.2103**	**1.3025**	**1.3347**

From Figure 3 and Appendix Table 3, it can be seen that with three-channel service (s=3), the minimum values of loss costs are:

- when k=2 and ρ=10,6 G_{min}=1.0011manat per minute=0,589 USD per minute
- when k=2 and ρ=5,6 G_{min}=0,9451 manat per minute=0,556 USD per minute
- when k=2 and ρ=1,6 G_{min}=1,1788 manat per minute=0, 693 USD per minute
- when k=3 and ρ=10,6 G_{min}=1,2103 manat per minute=0,720 USD per minute
- when k=3 and ρ=5,6 G_{min}=1,0791 manat per minute=0,635 USD per minute
- when k=3 and ρ=1,6 G_{min}=1,1813 manat per minute=0,695 USD per minute
- when k=4 and ρ=10,6 G_{min}=1,3025manat per minute=0,766 USD per minute
- when k=4 and ρ=5,6 G_{min}=1,1811 manat per minute=0,695 USD per minute
- when k=4 and ρ=1,6 G_{min}=1.1826 manat per minute=0,696 USD per minute
- when k=5 and ρ=10,6 G_{min}=1,3347 manat per minute=0,785USD per minute
- when k=5 and ρ=5,6 G_{min}=1,2498 manat per minute=0, 735USD per minute
- when k=5 and ρ=1,6 G_{min}=1,1832 manat per minute=0, 696USD per minute

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

Table 4

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**

Figure 5 and Appendix Table 4 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=1 and ρ=10.6 G_{min}=0.4564 manat per minute=0,268 USD per minute
- when k=1 and ρ=5.1 G_{min}=0.4527 manat per minute=0,266 USD per minute
- when k=1 and ρ=1.6 G_{min}=0.4103 manat per minute=0,241 USD per minute
- when k=2 and ρ=10.6 G_{min}=0.8933manat per minute=0,525 USD per minute
- when k=2 and ρ= 5.1 G_{min}=0,8517 manat per minute=0,501 USD per minute
- when k=2 and ρ=1.6 G_{min}=0.7380 manat per minute=0,434 USD per minute
- when k=3 and ρ=10.6 G_{min}=1.3025 manat per minute=0,766 USD per minute
- when k=3 and ρ=5.1 G_{min}=1.1565 manat per minute=0,680 USD per minute
- when k=3 and ρ=1,6 G_{min}=1.1826 manat per minute=0,700 USD per minute
- when k=4 and ρ=10.6 G_{min}=1.6557 manat per minute=0,970 USD per minute
- when k=4 and ρ=5.1 G_{min}=1.4085 manat per minute=0,830 USD per minute
- when k=4 and ρ=1.6 G_{min}=1.6908 manat per minute=0,990 USD per minut

Results

Based on the results presented, it can be concluded that when designing switching nodes operating under a combined service system, the found minimum values of loss cost for optimal load values and the number of waiting positions should be taken into account to optimize the number of channels and the number of waiting positions.
The proposed methodology and a numerical example of optimizing the parameters of a switching node operating under a combined service system demonstrate the possibility of selecting the optimal design option.
Based on the developed models, optimization methods, and the numerical results presented on a personal computer, the following conclusions can be drawn.

Conclusion

The practical value of the work lies in the fact that the scientific and theoretical results obtained can be used:
- in the calculation and evaluation of the quality indicators of the functioning of both designed and existing telecommunication nodes with limited queue and priority packet flow service;

- when calculating the time it takes for information to travel from the source to the recipient;
- when evaluating the coefficients of downtime and the efficient use of network resources;
- when calculating and optimizing the parameters of switching nodes operating under a combined service system.

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.

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 [1]. Insufficient attention was paid to the issue of the impact of changing conditions within the network on the effectiveness of different network protocols.

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]. S. Prakash explored the possibility of using cloud technologies to optimise the performance of communication networks [3]. 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 study by A. Tanenbaum and D. Wetherall explored the impact of load growth on the performance of communication networks [4]. 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.

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 calculating the 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 communication network "Elections" of the Republic of Azerbaijan has been studied.

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 [6].

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 study considers the effectiveness of quality of service (QoS), which is also the basis of this paper. O. Bonaventure [8] 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 [9] 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 [10] 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 [11] 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. [12] 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 [13] 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 research conducted in this work also relates to the performance analysis of telecommunication systems, and therefore the article provides valuable insights for researchers in this field. A particularly interesting example illustrates how analytical results can be used in conjunction with approximate methods and modeling to evaluate the performance of complex systems.

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