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DEVELOPMENT OF THE ANALYTICAL MODEL AND METHOD OF OPTIMIZATION OF THE PRIORITY SERVICE CORPORATE COMPUTER "ELECTIONS" NETWORK

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Abstract. *The main objective of this article is to provide recommendations for improving the quality of service indicators in priority service corporate computer networks, including the probability of denial of service attacks, the probability of timely and lossless information delivery, and the selection and effective use of equipment that meets modern requirements.*

Keywords: computer network, corporate, probability, priority, digital communication lines, switching devices

OPRACOWANIE MODELU ANALITYCZNEGO I METODY OPTYMALIZACJI PRIORYTETOWEJ OBSŁUGI KORPORACYJNEJ SIECI KOMPUTEROWEJ "WYBORY"

Streszczenie. *Głównym celem tego artykułu jest przedstawienie zaleceń dotyczących poprawy wskaźników jakości usług w korporacyjnych sieciach komputerowych z usługami priorytetowymi, w tym prawdopodobieństwa ataków typu "odmowa usługi", prawdopodobieństwa terminowego i bezstratnego dostarczania informacji oraz wyboru i efektywnego wykorzystania sprzętu spełniającego współczesne wymagania.*

Słowa kluczowe: sieć komputerowa, korporacja, prawdopodobieństwo, priorytet, cyfrowe linie komunikacyjne, urządzenia przełączające

Introduction

This work demonstrates that in a corporate computer network, the probability of request loss (P_j) depends on the intensity of incoming traffic in the j – communication channel and the number of parallel channels (s_j). The intensity of failures (c_j) has a negligible impact on changes in service quality (Q_j) due to the presence of parallel channels. The obtained tables and functional dependencies allow for the design of a corporate computer network operating with the required quality indicators, and to optimize the number of channels and waiting places, it is necessary to calculate the minimum values of loss cost functions, which depend on specific load values.

1. Materials and methods

"The functioning of an analytical model of a computer corporate network is being studied, the probabilities of loss and delivery on time of requests are defined. The operation of the computer corporate network "Elections" in the Republic of Azerbaijan has been examined" [13].

Analyses of corporate computer networks (telephone communications, digital networks with integrated services, etc.) are well described in [5, 9].

The use of optimization methods in network planning can reduce the cost of project implementation by up to 20% [4, 10]. There are stages of strategic, long-term, medium-term and current planning. Long-term (medium-term) planning determines the transition to a new communication network structure according to the criterion of minimum total capital costs. According to the position of the theory of systems, optimization of networks is decomposed on the problem of structural and parametric optimization. The first task is to select the optimal network structure, taking into account the requirements for its bandwidth, reliability, survivability and the types of computer equipment used. The second task is based on the development of mathematical models of the network and its elements, optimization of 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 [6, 7]:

$$P_j = \frac{r_j^{s_j}}{s_j!}\left(\sum_{n=0}^{s_j}\frac{r_j^n}{n!}\right)^{-1} \quad (1)$$

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 (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:

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

where $\bar{\mu}$ –is the average service intensity; s_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 – 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 (c_j) has little effect on changes in the quality of service (Q_j).

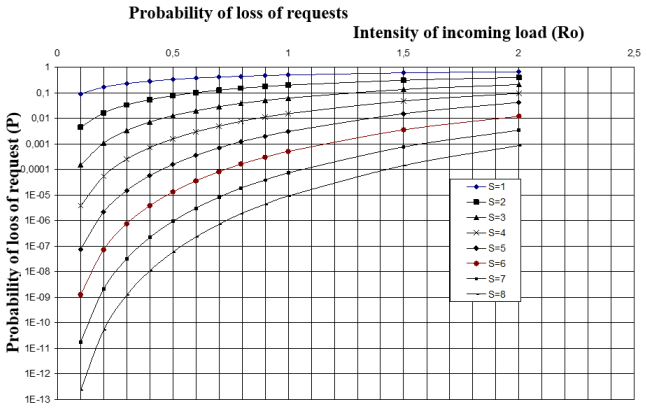

Fig. 1. Dependence of the probability of loss of requests (P_j) on the change in the incoming load in the j – communication path (ρ_j) and on the number of parallel channels (s_j)

2. Results and discussions

The results of this work were used in the design, development and operation of the computer corporate network "*Elections*". The computer corporate network "*Elections* R" was created by order No. 528 of the President of the Republic of Azerbaijan dated September 3, 2000 on the design of the state automated information system (SAIS). According to the created structure of the state automated information system (Fig. 3), the voting process and automatic transmission of information are carried out at three levels:

- at the Information Center of the Central Electoral Commission (CEC),
- in the information section of the district election commission (DEC),
- in the information section of the precinct election commission.

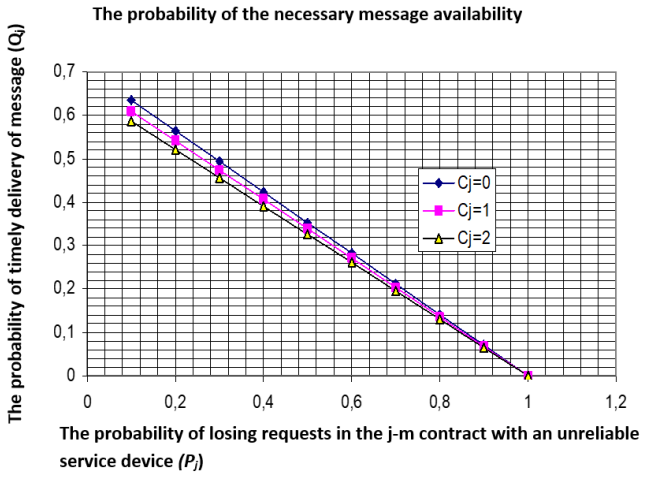

Fig. 2. Dependence of quality of service on the probability of loss of requests

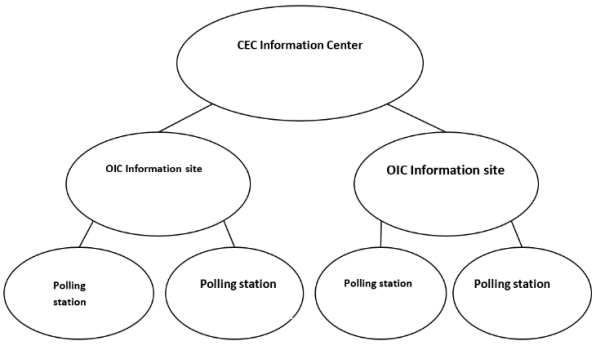

Fig. 3. Diagram illustrating the structure of the state automated information system

To organize the work of the SAIS, an information center "*Elections*" was created at the central election commission. The information center "*Elections*" is equipped with modern computer equipment, a webcam, telecommunication equipment and a special screen. The Center, using the state computer communication network, receives information from the district and district electoral commissions. The information center can simultaneously receive information from 125 constituencies. At present, according to the "Strategic Roadmap for the Development of Telecommunications and Information Technologies in the Republic of Azerbaijan", approved by the Decree of the President of the Republic of Azerbaijan dated December 6, 2016, the GAIS uses long-distance telephone channels and automatic telephone exchanges Ministry of Communications and High Technologies of the Republic of Azerbaijan (Ministry of Digital Development and Transport of the Republic of Azerbaijan) [13]. The information of the district election commission is sent to the information center "Elections" at a speed of 39.2 kbps.

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 main purpose of the study by R. de Moraes and F. Vasques [1] 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.

R. Ghimire and R. Noor [3] 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.

In research work [4], 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 [4].

The main research point of the paper authored by Z. Huseynov [5] is modeling and analysing the features of computer networks with prioritized services, including multi-channel and multi-node networks. Mathematical models have been formulated to enable the evaluation of the performance of contemporary computer networks, taking into account the quantity of channels, queuing capacity at network nodes, and the total number of network nodes. The suggested techniques for computing the likelihood of losses and the probability of on-time delivery of request flows enable the determination of real values for qualitative indicators of functioning. It is possible to agree with the authors that priority maintenance can significantly affect network performance. However, it is important to consider not only the number of channels and nodes, but also other factors, such as the type of traffic and bandwidth. In general, the paper presents an interesting look at the modelling and analysis of multi-channel and multi-channel computer networks with priority maintenance. It can be useful for researchers dealing with this topic and for those who want to improve the performance of their network.

The main purpose of the study of the document authored by B. Ibragimov et al. [6] is to analyse the performance metrics of multiservice telecommunication networks utilizing the architectural concept of future networks.. The paper proposes a mathematical model of the network. considering system performance, information security, and boundary quality indicators. The document also discusses the use of SDN & NFV and IMS technologies to support a wide range of multimedia services and the need to ensure fault tolerance, system throughput, and protection of threat information in MTS based on FN while ensuring guaranteed quality of service. The analysis conducted during the preparation of this paper is in agreement with the researcher in recognising that fault tolerance and information security are important quality criteria for the functioning of communication networks. However, the topic of this document is only indirectly related to the immediate topic of this work, being for the most part illustrations of other equally important aspects of the network besides efficiency and speed.

The document [7] 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 main research topic of the book by L. Kleinrock [8] 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 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 [9].

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

S. Prakash explored the possibility of using cloud technologies to optimise the performance of communication networks [2]. 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 [11]. 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 purpose of the study by L. Yangyong [12] 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.

In the "Strategic Roadmap for the Development of Telecommunications and Information Technologies in the Republic of Azerbaijan", approved by the Decree of the President of the Republic of Azerbaijan dated December 6, 2016, intercity telephone channels and automatic telephone exchanges of the Ministry of Communications and High Technologies of the Republic of Azerbaijan (Ministry of Digital Development and Transport of the Republic of Azerbaijan) were used [13].

3. Conclusion

Mathematical models and methods for optimizing a corporate 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, have been developed.

It is shown that models and methods for optimizing corporate computer networks, in order to ensure the required quality of operation, it is necessary to select the optimal number of channels (s), waiting places (k) in network nodes and loads of individual priorities. It has been revealed that with an increase in the number of network nodes (N), there is a need to increase the number of channels (s) and waiting places (k) in network nodes. The resulting tables and functional dependencies make it possible to design a corporate computer network with priority maintenance that operates with the required quality indicators.

It is shown that in a corporate computer network the probability of requests being lost (P_j) depends on the intensity j – of the incoming load in the communication path and on the number of parallel channels (s_j). The failure rate (c_j) has little effect on changes in quality of service (Q_j) due to the presence of parallel channels.

The work is confirmed by the fact that it was carried out in accordance with the plan for the design of the state automated information system (GAIS) "*Elections*", with the plan of the Ganja Telecommunications Department for the introduction of new equipment and technology.

Precinct election commissions use a special electronic box in which a scanner is installed, from which information is read into a computer. The electronic ballot box makes it possible to automate the transfer of information about the voting process to the district election commission and to the central information center "*Elections*". This makes it possible to conduct elections democratically, transparently, openly and quickly. This experience can be carried out in other countries.

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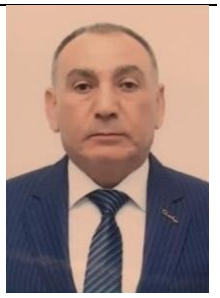

Huseynov Zakir was born 2 July 1955. In 1980 graduated from Kirovabad State Pedagogical Institute after named H. Zardabi, Mathematic Faculty. By the decree of the President of the Republic of Azerbaijan dated 03.10.2006, he was awarded the honorary title "Honored Teacher of the Republic". In 2012 he 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.

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