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Article

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ANALYTICAL ASPECTS OF APPLICATION OF INTELLIGENT METHODS OF MANAGEMENT OF COMPUTER SYSTEMS IN TRANSPORT INFRASTRUCTURE PROJECTS

The object of research is the processes of monitoring and intelligent control of computer systems in transport infrastructure projects. In the design and operation of computer networks, an urgent task is to solve the problem of providing quality services with distributed information processing, which is largely determined by the development of the network management mechanism of the transport system. The increase in the amount of digital data creates security and protection of information solely at the expense of the aspects of their design and operation. The paper considers the methods of intelligent network management of computer systems in transport infrastructure projects, analyzes their principles of operation and functions in relation to the network infrastructure. Methods using intelligent agents are analyzed and the results of their application to computer network management are presented. The use of intelligent agents in computer networks and systems allows automating complex tasks, optimizing resources and increasing the efficiency of the network of the transport economy system. They can contribute to increased productivity, safety, and user satisfaction.

The considered algorithms for processing the results of the examination of the load of the transport network infrastructure are used to ensure effective management of the transport system. Processing algorithms allow analyzing the current state of traffic in different sections of the transport network. These algorithms can be used to develop optimal traffic distribution strategies. A case of their application is presented.

One of the main tasks of the transport sector is to ensure traffic safety, which can be achieved by quickly processing information and receiving it distributed to all levels of the management system for quick analysis, processing, and (if necessary) response. The paper proposes to use methods of monitoring, expert evaluation of the general state of the computer network and the development of management decisions that take into account the peculiarities of the structure and functioning of computer systems in transport infrastructure projects.

This ensures the ability to transmit information with specified service quality parameters with minimal network resource consumption.

The research presented in this paper can be used in practice in organizations and enterprises of the transport sector during the reorganization, improvement, or integration of individual components of the information system.

Keywords: *monitoring, computer system, computer network, transport management, information processing.*

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1. Introduction

Methods of intelligent control of computer networks at transport enterprises are used to ensure increased efficiency and safety of transport systems. The use of intelligent computer network management methods at transport enterprises has several significant advantages:

– resource efficiency, which allows optimizing the use of network resources, such as bandwidth, devices, protocols, etc., which will reduce network maintenance costs, increase productivity and ensure system reliability;

– *automation and management optimization*: can automate many tasks related to the configuration, monitoring, and management of the network infrastructure. This reduces the dependence on manual operations, increases the speed of response to changes in the network, and ensures efficient system operation;

– *analytics and forecasting*: can analyze large amounts of data collected from the transport company's network

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and extract valuable information from it. This will allow identifying problems, predicting costs and efficiency, detect anomalies and taking measures to prevent possible problems;

– *security*, will improve the security of the transport company's network, detect various threats, such as cyber attacks or misconfiguration of network devices, and take measures to prevent them.

Intelligent management of computer networks covers the use of methods and technologies that help automate and optimize network management processes using intelligent algorithms and systems. One of the approaches to intelligent network management is the use of intelligent agents.

Intelligent agents are software entities that have the ability to perceive the surrounding system, make decisions and interact with other agents to achieve certain goals. In the context of network management, intelligent agents can automate the processes of monitoring, analyzing, managing, and restoring the network, respond to changes in the network environment, and solve problems without direct operator intervention.

The use of intelligent agents in combination with other methods and technologies of intelligent management can significantly increase the efficiency, flexibility and reliability of computer network management.

An analytical review of works on the use of intelligent agents in computer networks and systems is given in [1–5]. Namely, papers [1, 6] consider the issues of organizing the architecture of multiagent systems. Paper [1] is devoted to ensuring a given level of service quality with the help of intelligent agents. Paper [4] considers the issue of organizing mobile agents in computer networks.

The issues of traffic management in computer networks are considered in [5, 6]. In order to improve the efficiency of computer network management, [2, 7] proposed the use of a multilevel system of intelligent agents.

A three-level system of intelligent agents [3, 8] is considered to provide QoS in networks of asynchronous data transmission with mobile agents. The main goal of the proposed architecture is to provide a self-regulating network congestion management system through the interaction of intelligent agents. Agents dynamically manage the buffer space of switches and interact to reduce the cell loss rate while guaranteeing a guaranteed transmission delay limit. Most of the existing ways to ensure a given QoS are characterized by static resource management and control of congestion parameters. This approach is not optimal and can be improved by using intelligent agents.

The use of intelligent agents in computer systems in the transport sector can be useful for various problems, but especially for traffic management, resource allocation, management of systems for the location and distribution of transport hubs and infrastructure, passenger services, and improving safety in the transport sector. They can monitor the movement of vehicles, detect dangerous situations, and make recommendations to safety systems to prevent accidents [9]. They can also help manage security systems, such as license plate recognition systems or speed control systems.

The aim of this research is to analyze and apply new intelligent methods for managing the network infrastructure of transport, which will ensure the transmission of information with specified quality of service parameters at minimal cost of network resources.

Based on the analysis of network management systems, it can be concluded that today their main function is to inform the network administrator about changes in equipment states and implement control actions. The main work of network management – analyzing incoming data, determining the mode of network operation, as well as choosing a network management strategy is entirely up to a person.

2. Materials and Methods

The object of research is the processes of monitoring and intelligent control of computer systems in transport infrastructure projects.

The paper analyzes and describes the basic principles of operation of the main methods of intelligent control of computer networks, including:

Machine learning: the use of machine learning algorithms to analyze large amounts of data, including network flows, logs, network parameters, etc. Machine learning allows detecting anomalies, predicting bandwidth consumption, determining optimal routing paths, adapting network parameters, and much more.

Genetic algorithms: the use of genetic algorithm principles to solve optimization problems in networks. Genetic algorithms can be used to find the best settings for network parameters, such as optimal routers, bandwidth settings, and other parameters.

Data analytics: the use of data analysis methods to identify trends and anomalies in the network. This allows determining the timely resolution of the problem and taking some measures to resolve them.

Automated management: the use of an automated system for monitoring and managing a computer network. This includes automatic device configuration, dynamic resource management, automatic error detection and correction, and automatic network scaling.

Virtualization and containerization: the use of virtualization and containerization technologies to effectively manage network resources. This allows to quickly create, scale, and manage virtual networks and services.

SDN (Software-Defined Networking): the use of a software-defined network for centralized and programmable management of network devices. SDN allows network operators to manage traffic, settings, and policies through a centralized controller.

These methods of intelligent computer network management help to provide more efficient, automated and flexible management of networks of systems in transport infrastructure projects which is especially relevant in today's complex network environments. The use of intelligent agents in computer networks and systems allows for a greater level of automation, adaptability and efficiency of management.

3. Results and Discussion

Computer network management systems perform the following functions: identification of network equipment states; development of control actions; implementation of control actions on the control object [10].

If to imagine the state of telecommunication equipment as a point in a multidimensional space, and at the same time classify the entire space of possible equipment states, then the task of managing a corporate network can be reduced to the task of pattern recognition.

Table 1 shows a comparative analysis of the procedures for pattern recognition and computer network management, which shows that the main stages of the network management process are essentially identical to the corresponding stages of the pattern recognition process.

Table 1

Comparative analysis of pattern recognition and computer network management

Pattern recognition	Management of computer networks
Data collection	Collection of statistics on the functioning of network equipment
Formation of a training sample	Formation of reference values of network functioning parameters
Building decision rules	–
Classification of states that are presented	Comparison of the current network state with the reference one and control of decision-making deviations

In this regard, the use of pattern recognition methods in the process of managing the corporate network of the transport sector infrastructure will allow creating an intelligent control system that will not only respond to pre-programmed situations, but will also be able to provide certain logic for comparing data and heuristically analyze incoming information.

One of the most important tasks of computer network management systems is the monitoring task associated with the evaluation of statistical information according to the following criteria:

– System response time; bandwidth of a real or virtual communication channel between two end users of the network;
– Traffic intensity in individual segments and channels of the network;
– Probability of data distortion during its transmission through the network;
– Availability of the network or its specific transport service.

Without performance and reliability analysis tools, a network service provider or the information technology department of a transport enterprise will not be able to control, let alone provide the required level of service for end users of the network [11].

It is important to note that the successful solution of monitoring tasks largely depends on the quality of the selection of methods of examination and evaluation of statistical information criteria. To solve these problems, it is advisable to use expert evaluation methods.

The main task of an expert system is to research and develop programs that use knowledge and input procedures to solve problems that are difficult for experts. An additional desirable characteristic of such a system, which is considered by many to be the main one, is the ability of the system to comment on the course of its reasoning on demand [12].

Characteristics that expert systems usually have. These systems are focused on tasks for which there are no or unknown solution algorithms, allow users who do not know programming languages to independently develop tasks using their experience and knowledge, and allow them to achieve results that are no worse, and often better, than those achieved with the help of experts.

Sometimes, there are several additional characteristics that expert systems have [4]:

– they are developed for expertise in a specific field;
– can make decisions based on fuzzy data;
– able to explain a chain of reasoning;
– makes decisions based on the rules in its knowledge base;
– has the ability to learn.

If an expert system performs the functions of the database management system (DBMS), then sometimes an expert system completely replaces it, because it provides the user with all the necessary information for making a decision [6, 8]. Thus, an expert system is used for decision-making in cases where there are no decision-making methods, algorithms, or available information is not enough to make decisions.

The experts in this task can be the network administrator, users – customers of services, as well as an expert system based on a database and knowledge, which accumulates and processes information about the current state of the network and switching nodes. The knowledge base is used to obtain information about the situation and answers to specific questions. Users – customers of services can act as experts only on quality of service issues that may arise from irrational decisions of experts – professionals or an automated expert system. In other words, users – service customers play the role of feedback sources when setting up a human-machine control system.

At present, there is no generally accepted scientifically based classification of expert evaluation methods, let alone unambiguous recommendations for their application. However, ordinal scales are used in the construction of an algorithm for processing the results of the examination, which allows distinguishing between network traffic loads when the evaluation criterion is not explicitly specified.

As an example, let's look at the algorithms for processing the results of network load examination. Let m system administrators evaluate n nodes by l indicators. The evaluation results are represented as x_{ij}^h, where j is the number of the system administrator, i is the number of the node, h is the number of the comparison indicator (feature). If the assessment of node utilization was performed by the ranking method, then the values x_{ij}^h are the ranks. If the assessment of the node load is performed by the method of direct assessment or by the method of sequential comparison, then the values x_{ij}^h represent numbers from a certain segment of the numerical axis, or points. The processing of the assessment results significantly depends on the measurement methods considered.

Let's consider the case when the values x_{ij}^h ($i=1,\ldots,n$; $j=1,2,\ldots,m$; $h=1,2,\ldots,l$) are obtained by direct evaluation or sequential comparison, and x_{ij}^h are numbers or points. To obtain the full state of the network from administrators, it is possible to use the average score for each node [7, 9]:

$$x_i=\sum_{h=1}^{l}\sum_{j=1}^{m} q_h x_{ij}^h k_j \ (i=1,2,\ldots,n), \qquad (1)$$

where q_h are the weights of the comparison indicators of the nodes; k_j are the coefficients of administrators' competence.

The coefficients of the weights of indicators and administrators' competence are normalized values [7, 13] $\sum_{h=1}^{l} q_h=1;\ \sum_{j=1}^{m} k_j=1$. The weighting factors of the indicators

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can be determined by experts. If q_{hj} is the weighting factor of the h-th indicator provided by the j-th administrator, then the average weighting factor of the h-th indicator for all administrators is equal to $q_h=\sum_{j=1}^{m} q_{hj}k_j$ $(h=1,2,...,l)$.

The administrators' competence coefficients can be calculated based on the results of the node utilization assessment (1). The main idea behind this calculation is the assumption that the competence of network administrators should be assessed by the degree of consistency of their assessments with the assessment of the network monitoring system. The algorithm for calculating the administrators' competence coefficients is a recurrent procedure:

$$x_i^t=\sum_{j=1}^{m} x_{ij}k_j^{t-1},\ i=1,2,...,n; \tag{2}$$

$$\lambda^t=\sum_{i=1}^{n}\sum_{j=1}^{m} x_{ij}x_i^t,\ t=1,2,...; \tag{3}$$

$$k_j^t=\frac{1}{\lambda^1}\sum_{i=1}^{n} x_{ij}x_i^t;\ \sum_{j=1}^{m} k_j^t=1;\ j=1,2,...,m. \tag{4}$$

The calculations start from $t=1$. In (2), the initial values of the competence coefficients are assumed to be the same and equal to $k_j^o=1/\mathrm{m}$. Then, according to (2), the estimates of the node load by the monitoring system are equal to the arithmetic mean of the system administrators' estimates $x_i^1=\frac{1}{m}\sum_{j=1}^{m} x_{ij},\ i=1,2,...,n.$

Next, the value λ^1 is calculated by equal: $\lambda^t=\sum_{i=1}^{n}\sum_{j=1}^{m} x_{ij}x_i^t$ and the values of the competence coefficients of the first approximation by equal (4):

$$k_j^t=\frac{1}{\lambda^1}\sum_{i=1}^{n} x_{ij}x_i^t.$$

Using the competence coefficients of the first approximation, it is possible to repeat the entire process of calculation according to (2)–(4), and obtain the second approximations of the values x_i^2, λ^2, k_j^2. Repeating the recurrent procedure for calculating node scores and competence coefficients raises the question of convergence. To consider this issue, let's exclude variables k_j^{t-1} and x_i^t from (2), (4) and present these equations in vector form:

$$x^t=\frac{1}{\lambda^{t-1}}Bx^{t-1};\ k^t=\frac{1}{\lambda^t}Ck^{t-1}\ (t=1,2,...), \tag{5}$$

where the matrices M of dimension $n\times n$ and the matrices C of dimension $m\times m$ are equal to $M=XX'$, $C=X'X$, $X=\|x_{ij}\|$. The value λ^1 in equations (5) is determined by formula (3). If the matrices M and C are nonnegative and non-decomposable, then, as follows from the Perron-Frobenius theorem, when $t\to\infty$ the vectors x^t and k^t to the eigenvectors of the matrices M and C, corresponding to the maximum eigenvalues of these matrices $x=\lim_{t\to\infty} x^t$, $k=\lim_{t\to\infty} k^t$. The boundary values of the vectors x and k can be calculated from:

$$Mx=\lambda_B x,\ \sum_{i=1}^{n} x_i=1,\ |B-\lambda_B E|=0,$$

$$Ck=\lambda_C k,\ \sum_{j=1}^{m} k_j=1,\ |C-\lambda_C E|=0, \tag{6}$$

where λ_B, λ_C are the maximum eigenvalues of the matrices M and C.

The condition of non-negativity of matrices M and C is easily fulfilled by selecting non-negative elements x_{ij} of the matrix X of object evaluations by experts. The condition of non-decomposability of matrices M and C is practically fulfilled, since if these matrices are decomposable, it means that administrators and nodes are divided into independent groups. In this case, each group of administrators evaluates only the nodes of its group. It is known that it makes no sense to get a group score in this case. Thus, the conditions of non-negativity and non-decomposability of the matrices M and C, and hence the conditions of convergence of procedures (2)–(4) are fulfilled in practical conditions. It should be noted that the practical calculation of the vectors of group assessment of node load and competence coefficients is easier to perform using the recurrent formulas (2)–(4). Determining the boundary values of these vectors requires the use of computer technology. It is also possible to consider the case when system administrators evaluate many objects by the ranking method.

The use of intelligent methods of computer network management at transport enterprises, especially at critical infrastructure facilities, has significant strategic and tactical potential in wartime. In wartime, fast and reliable communication between military units and command centers is critical. Intelligent management of computer networks ensures efficient data transfer, security, and protection of the network infrastructure of the transportation sector. This allows operational teams to receive real-time information and make quick and informed decisions.

In a time of war, it is important to optimize the use of available network resources as much as possible. Intelligent network management allows to efficiently distribute bandwidth, energy and other resources between free systems and devices, ensuring optimal network performance.

Intelligent algorithms can analyze a large amount of data coming from various sources (e. g., satellites, drones, sensors, etc.). This allows them to detect anomalies, recognize patterns, and predict threats. Such monitoring and analytics help to ensure operational control over the network infrastructure and respond to changes in a timely manner.

The prospect of further research is the possibility of applying various methods of intelligent management of computer networks to generate control data based on predictive data. It will also allow developing methods and architecture of a decentralized control network, when technical management of the network is carried out for each autonomous segment separately, and organizational management for the network as a whole.

When using methods of intelligent network management, practitioners should carefully analyze the limits of application and take them into account during development and implementation. Application boundaries such as automation of network operations, traffic analysis and optimization, network monitoring and security, bandwidth and resource management, and quality of service management should be taken into account.

Quantitative indicators have their limits and ranges of values. For example, the bandwidth of the network may be limited by the physical characteristics of the network equipment according to the component system of the transport infrastructure of the sector. Practitioners should be aware of the limitations of the scale of indicators and take them into account when evaluating and managing the network.

4. Conclusions

The paper analyzes new methods of intelligent control of computer systems in transport infrastructure projects. Intelligent agents were used to consider intelligent control, which will allow solving the problems of quality services with distributed information processing.

Intelligent agents are powerful tools in computer networks and systems. They are used to automating, optimize, and improve various aspects of networks and systems in the transport infrastructure, namely to monitor and manage network traffic, to automate routine network operations such as configuration, monitoring, and management of network devices, and to distribute tasks in networks and systems. They can analyze the characteristics of tasks and resources, identifying shortcomings and limitations, and distribute tasks among network nodes or devices for optimal resource utilization.

The use of intelligent agents in combination with other intelligent management methods and technologies can significantly increase the efficiency, flexibility, and reliability of computer network management.

The algorithms for processing the results of the examination of the transport network infrastructure load, an example of which was developed in this work, allow supporting various studies and analyzing data related to the load of the transport network.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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References

1. Carter, J., Ghorbani, A. A., Marsh, S. (2002). Just-in-time information sharing architectures in multi-agent system. *Proceedings of AAMAS*. Bologna, 647–654. doi: https://doi.org/10.1145/544862.544893
2. Mostagir, M., Decker, K. (2002). A multi-agent system architecture for active Networks. *Proceedings of AAMAS 2002*. Bologna, 1417–1418. doi: https://doi.org/10.1145/545056.545146
3. Boutaba, R., Iraqi, Y., Mehaoua, A. (2003). A multi-agent architecture for QoS management in multimedia networks. *Journal of Network and Systems Management, 11 (1),* 83–107. doi: https://doi.org/10.1023/a:1022497125456
4. Papavassiliou, S., Puliafito, A., Tomarchio, O., Ye, J. (2002). Mobile agent-based approach for efficient network management and resource allocation: framework and applications. *IEEE Journal on Selected Areas in Communications, 20 (4),* 858–872. doi: https://doi.org/10.1109/jsac.2002.1003050
5. Iraqi, Y., Boutaba, R., Garcia, A. L. (2000). QoS control in wireless ATM. *Mobile Networks and Applications, 5,* 137–145. doi: https://doi.org/10.1023/a:1019148226421
6. Holub, H., Kulbovskyi, I., Kharuta, V., Tkachuk, M., Tymoshchuk, O. (2021). Methods of Intelligent Data Processing of the System of Control and Diagnostics of Electric Power Transport Objects. *25rd International Scientific Conference on Transport Means 2021*. Kaunas, 797–801.
7. Carter, J., Ghorbani, A. A., Spencer, B. (2001). Agent design considerations withindistributed information retrieval systems. *Proceedings of the Workshop of Novel E-Commerce Applications of Agents*. Ottawa, 23–28.
8. Bohdanova, N. V. (2006). Method of inerease of control effectiveness in telecommunications systems. *Adaptive systems of automatic control, 1 (9),* 23–32. doi: https://doi.org/10.20535/1560-8956.9.2006.37488
9. Kulbovskyi, I., Holub, H., Skliarenko, I., Bambura, O., Soloviova, O. (2019). Development of a system model for the functioning of distribution electrical supply systems in transport infrastructure projects. *Technology Audit and Production Reserves, 4 (2 (48)),* 24–28. doi: https://doi.org/10.15587/2312-8372.2019.179260
10. Vasylevska, A. (2012). Upravlinnia proektamy pidpryemstva iz zastosuvanniam informatsiinykh tekhnolohii. *Visnyk Kyivskoho natsionalnoho torhovelno-ekonomichnoho universytetu, 1,* 99–105.
11. Plugina, Iu. A. (2010). Upravlenie razvitiem kak optimalnaia model upravleniia predpriiatiem. *Vestnik ekonomiki transporta i promyshlennosti, 30,* 89–93.
12. Kulbovskyi, I. I. (2010). Metodyka pobudovy systemnoi modeli funktsionuvannia vyrobno-tekhnolohichnoho potentsialu pidrozdiliv koliinoho hospodarstva metropolitenu. *Transporti systemy i tekhnolohii, 17,* 61–66.
13. Stohnii, B. S., Kyrylenko, O. V., Denysiuk, S. P. (2010). Intelektualni elektrychni merezhi elektroenerhetychnykh system ta yikh tekhnolohichne zabezpechennia. *Tekhnichna elektrodynamika, 6,* 44–50.

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