UDC 004.94

V. KOSENKO, E. PERSIYANOVA, O. BELOTSKYY, O. MALYEYEVA

METHODS OF MANAGING TRAFFIC DISTRIBUTION IN INFORMATION AND COMMUNICATION NETWORKS OF CRITICAL INFRASTRUCTURE SYSTEMS

The **subject** matter of the article is information and communication networks (ICN) of critical infrastructure systems (CIS). The **goal** of the work is to create methods for managing the data flows and resources of the ICN of CIS to improve the efficiency of information processing. The following **tasks** were solved in the article: the data flow model of multi-level ICN structure was developed, the method of adaptive distribution of data flows was developed, the method of network resource assignment to multi-server nodes was developed. The following **methods** used are –methods of mathematical statistics for random processes, the theory of queuing systems, methods of optimization theory and operations research. The following **results** were obtained – the principles of managing the distribution of network traffic in the ICN of CIS were formulated and the practical requirements arising in the efficiency of data transmission were determined. The possible approaches to the formulation and solution of the listed problems were suggested according to the developed general approach to network management. The multi-level information structure was investigated. The mathematical model of data flows of a multilevel information structure of the network was developed; it has a three-level unstratified structure and consists of a number of subnets and groups of nodes. The method for adaptive management of data flows distribution was developed; this method includes the stratified two-level management which is based on the development of a multidimensional space of the network state and management parameters taking into account user activities. The management is carried out at the first level by setting the basic parameters of the network, at the second – by operational management with constant basic parameters. The method for distributing the resources of a multi-server information processing node was developed, as server systems are considered as a set of single-line queuing systems and information about the distribution of the bandwidth of communication channels is used. **Conclusions:** using the method of the adaptive management of traffic distribution enables reducing the time for processing system transactions and total costs for maintenance. The use of the method resource distribution of the server node in the course of re-engineering CIS processes minimizes the costs of servicing the data flows.

Keywords: information and communication network, critical infrastructure system, traffic distribution, multi-server node, data flows.

Introduction

At the current stage of the development of critical infrastructure systems (CIS), changes in management are due to such factors as updating technical equipment, expanding the territorial scope, increasing the dynamics of the implementation of functional tasks, changing their nature and content, new technological modes of operation. In order to provide information exchange in the course of CIS operation, a single information and communication network is developed and the system of the communication and automation gradually transform to the update digital means of transmission and processing of information, to the automation of management processes [1].

Nowadays, the systems of critical infrastructure are characterized by the high intensity of data flows in the management process and the requirements for the efficiency of management, timely decision making and bringing to the executors of solutions and tasks are constantly rising [2]. In the distributed information and communication network (DICN), it is difficult to provide the required response time very difficult because of the high intensity and variety of data flows as well as due to the need to search data in large-scale repositories and databases, the complex interaction of distributed applications, the low speed of communication lines, the declaration of non-homogeneous components interaction among various ICN subnets.

The main advantages of many control systems – universality and multifunctionality quite often become the main disadvantages in CIS as the specifics of the work of the system which requires appropriate network settings and methods of managing should be taken into consideration [3].

According to the mentioned above, the development of the methods of managing the distribution of the network traffic that are aimed at solving a given set of applied tasks and at ensuring the CIS required security within the ICN environment is of primary importance.

The analysis of the problem and available methods

While upgrading the ICN of CIS, particular attention is paid to increasing the bandwidth of channels and communication lines and finding new technical solutions that enable improving the characteristics of management processes [4].

However, a feature of many multiservice ICNs is the specific fluctuation profiles of the data flow traffic, so the ICN potential can be fully implemented only due to the efficient adaptive management of available network resources under growing requirements for the speed of information exchange.

At present, much attention is paid to the study and development of methods for building information and telecommunication networks and distributed information systems [5]. Data flows in present ICNs are characterized by heterogeneity and significant spread of parameters, which is caused by their multiservice nature, the various formats of data obtained from different sources.

Statistical analysis, mathematical modelling, static and dynamic analysis of sources and data flows are used for analyzing data flows and determining their parameters [6].

However, modelling of data flows should be based on the study of the information structure of the network. This enables the efficient use of network resources, ensuring compliance with the requirements for the reliability and speed of information processing. One of the

Сучасний стан наукових досліджень та технологій в промисловості. 2017. № 2 (2) *ISSN 2522-9818 (print)*

most promising directions for the development of methods for ICN building is the use of adaptive control methods [7].

At present, the task of studying, analyzing and modelling data flows that arise in the process of operation and interoperability of applications in a network is not formalized and requires developing the models that reflect the information and technical structure of the network and data flows available in ICN.

Traffic distribution management involves using both standard methods and algorithms of traffic management and the ones developed by users. These methods are linked with the optimization of the network performance which includes technology and scientific principles of measurement, modelling, describing and managing traffic to obtain the required performance characteristics [8]. Traffic management focuses on minimizing the loss of packets and delays, optimizing the bandwidth and agreement of the best service level.

The central function of traffic management is efficient management of bandwidth due to the optimal assignment of traffic to switching nodes. At present, different methods of traffic management are used in CIS. Most of them assume the possibility of external parametrization, that is, the transmission of traffic parameters directly to used control algorithms. Some methods, such as, for example, the method of multiprotocol label switching of packets allow the modification or replacement of management algorithms that are a part of the management technology that is being implemented [9].

In present ICNs, a user can modify the software that controls the data transmission activity (DTA) at two levels of data flow management.

The lower level of management involves using management algorithms where the estimates for the DTA parameters obtained due to the methods that take into account the features of the data flows are transmitted. To obtain the estimates of the DTA parameters at this level, the following methods can be used [10, 11]:

- the method for estimating the size of the filtering buffers of the communication equipment;
- the method for synthesizing the stable estimation of the function of the traffic distribution density;
- the methods for managing the redistribution of virtual connection bandwidth taking into account priorities and competition among integral data streams.

The consistent application of the methods mentioned above as well as similar ones enable obtaining the estimates of traffic control parameters. The analyzed methods of the traffic distribution are summarized in Table 1.

Table 1. *Basic methods of redistribution of the network resources*

Methods	Peculiarities	Advantages	Disadvantages
Method of statistical multiplexing	implement the technology and scientific principles of measurement, modelling, description and management of traffic to obtain the required characteristics.	smooth the profile of data flows traffic	do not take into account the properties of traffic, as when the peak values of data density occur, their commencement and short duration cannot be taken into account
The method of smoothing the data flow density			
Method of assessing the size of the filtering buffers of the communication equipment	selects the optimal size of filter buffers for integral data flows that are served by a virtual channel.	enables increasing the bandwidth of virtual channels	are not used for traffic management at the upper level of management (to govern the access when receiving a query for data transfer)
The method of synthesis of a stable estimation of the function of density of traffic distribution	analyzes the integral flow of fractal data	enables getting adequate assessment of control parameters	
Methods for managing the redistribution of virtual connection bandwidth	is used while dynamic reserving the bandwidth	takes into account priorities and competition among integral data flows	

Methods of traffic management should take into account the features of the management of hierarchical systems and be based on the following principles of traffic distribution management [12]:

- the principle of decomposition;
- the principle of coordinating subnetworks operation;
- the principle of correlation the objectives of subnet management.

The traffic management includes a set of interconnected network elements, the system of monitoring the network state, a set of means for managing the configuration as a response to the current state of the network, and enables taking actions that prevent unwanted future states using the prediction of the state and trends of traffic development.

The goal of the article is to develop the methods of managing the flows and resources of CIS ICN to increase the speed of data processing. The article solves the following tasks:

- creating the model of data flows of the ICN multilevel structure,
- developing the method of adaptive distribution of data flows,
- developing the method for distributing network resources for a multi-server node.

Solving the task

Information and communicative networks have a multi-level structure according to CIS [13]. Let us consider the network aggregated at three levels (fig. 1):

- nodes assigned to the system users;
- groups of nodes that correspond to functional tasks;

- subnetworks that correspond to the system subsystems.

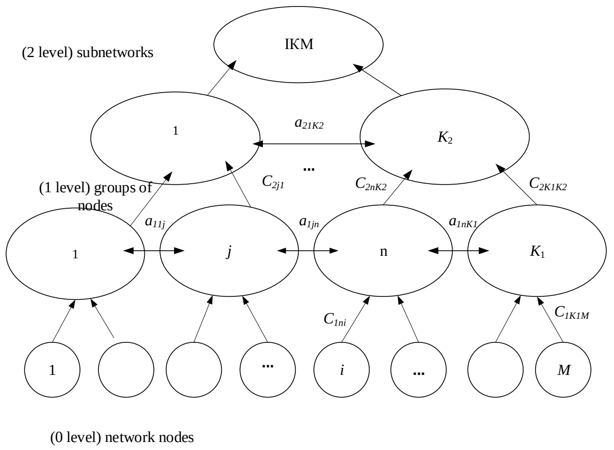

Fig. 1. Generalized diagram of the stratified ICN information structure

The main characteristics of this structure are the total density of data flows at each level and the absorbance between the levels (table 2).

Table 2. *The parameters of data flows of a three-level stratified structure of ICN*

Parameters	The structure level	Designation
total density of data flows	first (groups of nodes)	A_{10}^*
	second (subnetworks)	$A_{20}^*\ \mathbf{A_1}\ \mathbf{C}_1$
total density of data flows in the middle of subnetwork	first	$A_1^*\ \mathbf{A_1}\ \mathbf{C}_1$
	second	$A_2^*\ \mathbf{A}_2\ \mathbf{C}_2$
absorbance	first	$\sigma_1\ \mathbf{C}_1$
	second	$\sigma_2\ \mathbf{C}_2$

To determine these characteristics, the model of the data flows of a multi-level information structure of the network is suggested.

Let us suppose that all network nodes are divided into k1 groups (group number $n = \overline{1, k_1}$). Each group number n is given by the column vector

$$c_{1n}^{\ T} = c_{1n1}, ..., c_{1ni}, ..., c_{1nt} \ ,$$

where $c_{1ni} = \begin{cases} 1, \text{ if the node } i \text{ is part of the group } n \\ 0, \text{ if the node } i \text{ is not part of the group } n \end{cases}$,

$$\sum_{i=1}^{t} c_{1ni} \geq 1, \ \sum_{n=1}^{k_1} c_{1ni} = 1 .$$

The matrix that groups the network nodes $C_1 = \|c_{1n}\|$ from the column vectors c_{1n}. The total densities of data flows that are transmitted among the network nodes while solving all the tasks are determined by the matrix $A = \|\alpha_{ij}\|$, where α_{ij} is the total density of data flows from the node i to the node *j*:

The densities of data flows among the groups can be calculated:

$$A_1\ C_1 = \|a_{1ij}\| = C_1 A\ C_1^{\ T} ,$$

where a_{1ij} is the total density of data flows between the *i*-th group of nodes and the *j*-th group of nodes of the network information structure:

$$a_{1ij} = \sum_{k=1}^{t} c_{1jk} \sum_{r=1}^{t} c_{1ir} a_{rk} \ .$$

The density of data flows of one task among the groups can be calculated. Thus, for the kth task

$$A_{1k}\ C_1 = \|a_{1kij}\| = C_1 A_k\ C_1^{\ T} ,$$

where a_{1kij} is the total density of data flows of the kth task between the rth group of nodes and the *j*-th group of nodes of the network information structure

$$a_{1kij} = \sum_{m=1}^{t} c_{1jm} \sum_{r=1}^{t} c_{1ir} a_{krm} \ .$$

The obtained results enable assessing the data flows, respectively, loading the ICN structure-forming equipment at the first level in general and the flows of each task.

For the second level of the structure, the matrix that divides the first level groups into groups of the second level can be defined in the same way as well as the density of data flows among the groups of the second level and the density of the data flows of one task among the groups of the second level.

The total density of data flows in the network of the first level nodes:

$$A_{10}^* = \sum_{i=1}^{t} \sum_{j=1}^{t} a_{ij} \ .$$

The total density of the data flows in the middle of the first level groups

$$A_1^*\ \mathbf{A_1}\ \mathbf{C}_1 = \sum_{i=1}^{K_1} a_{1ii} \ ,$$

where $\mathbf{A_1}\ \mathbf{C}_1$ is the total density of data flows that are transmitted only in the middle of the first level groups.

The total density of data flows at the second level:

$$A_{20}^*\ \mathbf{A_1}\ \mathbf{C}_1 = \sum_{i=1}^{k_1} \sum_{j=1}^{k_1} a_{1ij} - \sum_{i=1}^{k_1} a_{1ii} \ ,$$

the density of data flows in the middle of the second level groups:

$$A_2^*\ \mathbf{A}_2\ \mathbf{C}_2 = \sum_{i=1}^{k_1} a_{2ii} \ .$$

As a measure of the structure efficiency, the absorbance of the data flows densities at each level is used. The absorbance for the first level:

$$\sigma_1\ \mathbf{C}_1 = \frac{A_1^*\ \mathbf{A_1}\ \mathbf{C}_1}{A_{10}^*\ \mathbf{A_1}\ \mathbf{C}_1},\ 0 < \sigma_1 < 1.$$

The absorbance for the second level:

$$\sigma_2\ \mathbf{C}_2 = \frac{A_2^*\ \mathbf{A}_2\ \mathbf{C}_2}{A_{20}^*\ \mathbf{A}_2\ \mathbf{C}_2},\ 0 < \sigma_2 < 1.$$

The obtained result enables calculating the density of the data flows among the nodes within the group as well as the exchange of data among subnets to determine the load of communication channels and network equipment.

After the synthesis of the network structure, the task of managing traffic should be solved. The following factors that affect data flows in information and communication networks for loading communication channels and network equipment are as follows [14]:

- assigning system applications to the network nodes;
- assigning users to the network nodes;
- the density of queries flows for running applications (tasks);
- the structure of the network which specifies communication channels within the network equipment and the assignment of workstations and servers to the network equipment;
- the values of bandwidths of communication channels that are used in the network;
- the bandwidth of network equipment;
- the distribution of bandwidth of communication channels among individual tasks (task groups);
- routing data flows on the network.

However, the density of the queries flows, the composition of the users and the composition of the tasks can change over time, in addition, with the development of the network, the composition of the equipment and its parameters changes, that is, the basic parameters of the network change. All this causes the need for correction or change of control parameters of the network to achieve the necessary efficiency of its operation. The required values of performance indicators of the network related to the solution of applications should be provided [15]. To solve the given task, the method of adaptive management of data flows distribution is suggested; this method includes the following stages (fig. 2):

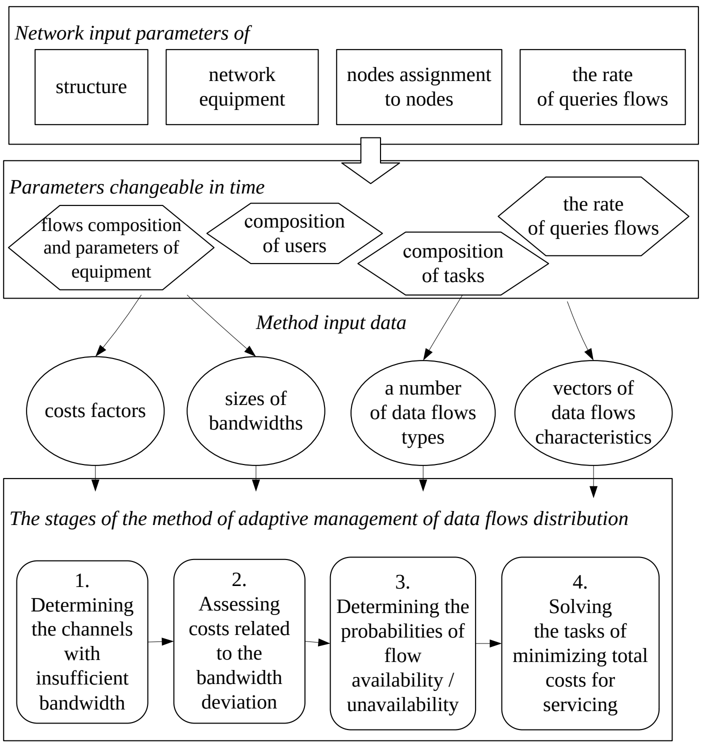

Fig. 2. The diagram of the method of adaptive management of data flows distribution

Determining the channels with insufficient bandwidth.

The bandwidth if not sufficient to meet the requirements of all types of flows, if

$$\sum_{k=1}^{\chi} \sigma_k < \sigma_\Sigma,$$

where σ_k is the bandwidth of the kth type; σ_Σ is the general bandwidth of the communication channel; χ is a number of flows types.

2. Assessing the costs related to the deviation of the bandwidth of the flow of k-th-type μ_k from the required σ_k.

The value of the costs related to the deviation of the distributed one is determined as:

$$s_k\ \sigma_k, \mu_k\ = \sigma_k - \mu_k\ \ \delta_k(a_k - b_k)\ \sigma_k - \mu_k\ + b_k\ ,$$

where $a_k \geq 0$ is the amount of the penalty for the downward deviation per a nominal unit;

$b_k \geq 0$ is the amount of the extra pay for a nominal unit of a greater bandwidth;

$$\delta_k \ \sigma_k - \mu_k \ = \begin{cases} 1 \ if \ (\sigma_k - \mu_k) \geq 0 \\ 0, \ if \ (\sigma_k - \mu_k) < 0 \end{cases}.$$

Then, the total amount of costs for servicing the flows is:

$$S \ \bar{a}, \bar{b}, \bar{\sigma}, \bar{\mu}, \bar{p}, \bar{q} \ =$$

$$= \sum_{k=1}^{\chi} p_k \ \sigma_k - \mu_k \ \ \delta_k (a_k - b_k) \ \sigma_k - \mu_k \ + b_k \ + q_k b_k \mu_k \ ,$$

where $\bar{a} = \ a_k$ i $\bar{b} = \ b_k$ are the vectors of costs factors;

$\bar{\sigma} = \ \sigma_k$ is the vector of set values of bandwidths;

$\bar{\mu} = \ \mu_k$ the vector of values of actual bandwidths;

$\bar{p} = \ p_k$ is the vector of the probability of the fact the given flow is transmitted via the channel;

$\bar{q} = \ q_k$ is the vector of the probability of the fact the given flow is not transmitted via the channel.

And the density of the flow of the kth type $\nu_k = \sigma_k$.

3. Calculating the probability of flow availability /unavailability.

Let the interval duration when the flow enters the channel (φ_k) and the duration of the interval when the flow does not enter the channel (ψ_k) be random values with the distribution functions $F_{\varphi_k}(t)$ i $F_{\psi_k}(t)$. Then the probabilities of the fact that the flows of the kth type is available or is not available in the channel are determined as:

$$p_k = \frac{\nu_{1\varphi k}}{\nu_{1\varphi k} + \nu_{1\psi k}} \text{ and } q_k = \frac{\nu_{1\psi k}}{\nu_{1\varphi k} + \nu_{1\psi k}}.$$

4. Calculating the task of minimizing total costs for servicing.

The value $\bar{\mu}^*$ should be found, when

$$S \ \bar{a}, \bar{b}, \bar{\sigma}, \bar{\mu}^*, \bar{p}, \bar{q} \ = \min_{\bar{\mu}} S \ \bar{a}, \bar{b}, \bar{\sigma}, \bar{\mu}, \bar{p}, \bar{q}$$

and the constraints are met:

$$\sum_{k=1}^{\chi} \mu_k \leq \sigma_{\Sigma} ; \ \sum_{k=1}^{\chi} \sigma_k > \sigma_{\Sigma} .$$

The developed method enables taking into consideration the probable change of requirements of applied tasks or users' activity for various types of communication channels so that total costs for data transmission can be changed. When the CIS processes are re-engineered, a number of users can be increased as well as the densities of the flows of queries for completing tasks [16]. Taking into consideration that the centralized methods of data processing and storing are used in CIS, the method of distributing network resources in a multi-server mode is developed (fig. 3).

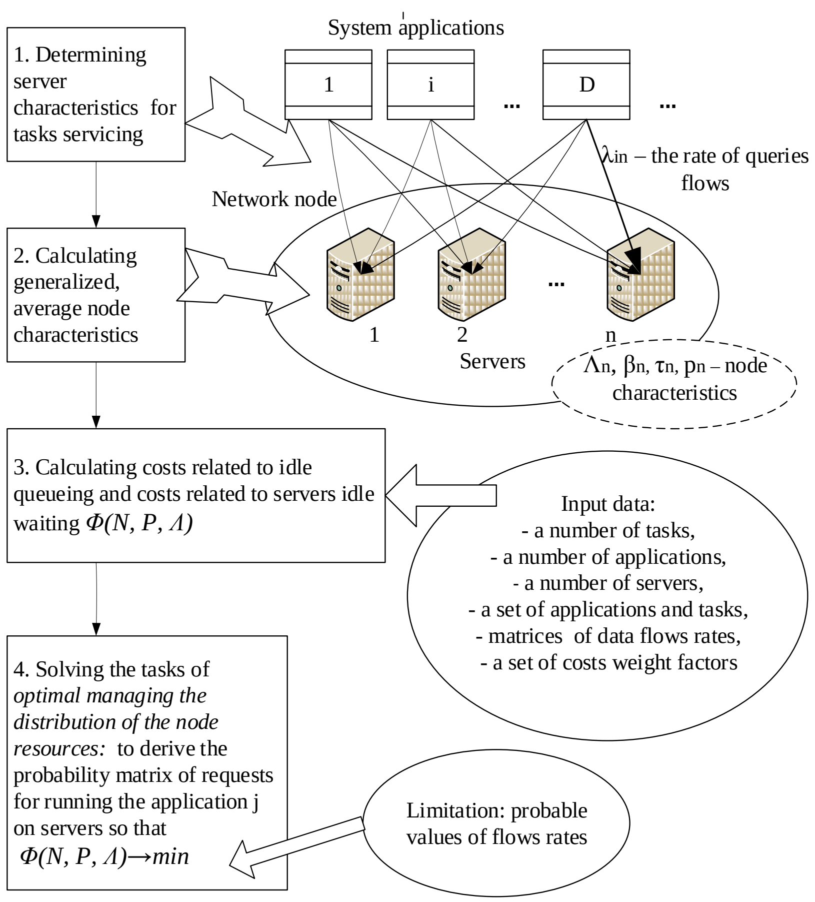

Fig. 3. The sequence of stages of the method of distributing resources of a multi-server data processing node

The method comprises the following stages:

1. Determining the server characteristics.

The densities of queries flows for completing the ith application, the vector $\Lambda = \lambda_i$, $i = \overline{1,d}$ is created. The matrix of the probability of the query for running the application i on the server n are determined as $P = \|p_{in}\|$ The value of the operational duration of i application on the nth server dn is a random value with the distribution function Fni(t). A bunch of single-line queueing systems of **M/g/1**/∞ type can be considered as a model of the system of servers. The density of queries flows for running the ith application that is fed to the input of the nth queueing system is determined as:

$$\lambda_{in} = \lambda_i p_{in}, \quad i = \overline{1,d}, n = \overline{1,\eta}.$$

2. Calculating total and average characteristics.

Such characteristics are calculated as:

- the density of the total flow of queries to the nth server:

$$\Lambda_n = \sum_{i=1}^{d} \lambda_{in} = \sum_{i=1}^{d} \lambda_i p_{in}, \quad n = \overline{1,\eta}.$$

- the probability of the fact that the query from the queue to the *n*-th server will the query of the ith application:

$$q_{in} = \frac{\lambda_{in}}{\Lambda_n}, \quad n = \overline{1,\eta}.$$

- the function of distributing the duration of processing the random query on the nth server:

$$\beta_n(s) = \sum_{i=1}^{d} q_{in}\beta_{ni}(s), \quad n = \overline{1,\eta},$$

where

$$\beta_{ni}(s) = \int_0^{\infty} e^{-st} dF_{ni}(t).$$

- is the average time for waiting for a query in the queue:

$$\tau_n = \frac{\Lambda_n \nu_{2n}}{2\ 1 - \Lambda_n \nu_{1n}}, \quad n = \overline{1,\eta},$$

$$\nu_{1n} = \int_0^{\infty} t dF_n(t) < \infty; \ \nu_{2n} = \int_0^{\infty} t^2 dF_n(t) < \infty.$$

– is the probability of the server idle waiting:

$$p_{0n} = 1 - \Lambda_n \nu_{1n}, \quad n = \overline{1,\eta}.$$

3. Calculating the costs related to the queries idle queueing:

$$F\ N, P, \Lambda\ = \sum_{n=1}^{\eta} \alpha_n \tau_n + \beta_n p_{0n}\ ,$$

where α_n i β_n are penalties for query queueing and nth server idle waiting.

4. Solving the optimization task with the target function:

$$F\ N, P^*, \Lambda\ = \min_P \sum_{n=1}^{\eta} \alpha_n \tau_n\ P, \Lambda\ + \beta_n p_{0n}\ P, \Lambda$$

under the constraints:

$$\sum_{n=1}^{\eta} p_{in} = 1, i \in \overline{1,d};$$

$$\sum_{i=1}^{d} p_{in} = 1, n \in \overline{1,\eta};$$

$$\Lambda_n \nu_{1n} < 1, n = \overline{1,\eta},$$

$$p_{in} = p_{in}^*, i = \overline{1,d}, n = \overline{1,\eta},$$

where p_{in}^* is the elements of the Boolean matrix that determine queries for servicing by particular servers.

Conclusions

The principles of managing the distribution of network traffic in CIS ICN are formulated and the practical requirements for the speed of data transmission are defined. The probabilities of applying the general principles of managing a complex system are determined

The goals and objectives of traffic management with the account of the specificity of applied CIS tasks operation and the requirements for the characteristics of their operation are considered. Possible approaches to the formulation and solution of the listed tasks in accordance with the developed general approach to the network management are emphasized.

The multi-level information structure was studied. The research enabled setting the rule of storing flows when transmitting data within each level of the structure. This rule allows the nodes to be grouped while synthesizing the structure of the network taking into account the capabilities of the network equipment. The mathematical model of data flows of a multi-level information network structure which has a three-level stratified structure and consists of a number of subnets and groups of nodes is developed. The densities of data flows among the nodes within a group can be calculated on the basis of this model and the data exchange among the subnets can be analyzed in order to determine the loading of communication channels and the network equipment of the CIS ICN.

The method of adaptive management of the distribution of data flows is developed, this method involves stratified two-level management which is based on the development of a multidimensional space of the network state and control parameters taking into account the activities of users. The use of this method enables reducing the time for processing system transactions and the total costs for servicing. The management is carried out at the first level by debugging the basic parameters of the network and on the second level – by the operational control when the basic parameters are constant. Reducing The time of transaction processing is reduced because of the decomposition of the network structure in the course of operational management of traffic distribution.

The method for distributing resources of a multi-server data processing node is developed due to the fact that server systems are considered as a set of one-line queueing systems and information about distributing the bandwidth of communication channels is used. The application of the method minimizes the costs for servicing data flows while reengineering CIS processes.

References

1. Biryukov, D. S., Kondratov, S. I. (2012), *Protection of critical infrastructure: problems and prospects of implementation in Ukraine* [Zakhyst krytychnoyi infrastruktury: problemy ta perspektyvy vprovadzhennya v Ukrayini]. Kyiv : NISS. 96 p. http://www.niss.gov.ua/content/articles/files/Sots_zahust-86178.pdf
2. Council Directive 2008/114/EC "On the identification and designation of European critical infrastructures and the assessment of the need to improve their protection". Available at : http://eurlex.europa.eu.
3. Konakh, V. K. (2014), *National Information Space of Ukraine: Problems of Formation and State Regulation: Analytical Reports* [Natsional nyy informatsiynyy prostir Ukrayiny: problemy formuvannya ta derzhavnoho rehulyuvannya : analit. Dop]. Kyiv : NISS. 76 p.
4. Kosenko, V, Bugas, D (2015), "Effectiveness analysis of resource usage of multiservice information and telecommunication network". *Technology audit and production reserves*. Vol. 5. No. 2 (25). P. 19–23. DOI: 10.15587/2312-8372.2015.51710.
5. Mangili, M., Martignon, F., Capone, A. (2015), "Optimal design of Information Centric Networks Original". *Computer Networks*. Vol. 91. P. 638–653. DOI: 10.1016/j.comnet.2015.09.003.
6. Sen, G., Krishnamoorthy, M., Rangaraj, N., Narayanan, V. (2015), "Exact approaches for static data segment allocation problem in an information network". *Computers & Operations Research*. Vol. 62. P. 282–295. DOI: 10.1016/j.cor.2014.05.023.
7. Xi, N., Sun, C., Ma, J., Shen, Y. (2015), "Secure service composition with information flow control in service clouds". *Future Generation Computer Systems.* Vol. 49. P. 142–148. DOI: 10.1016/j.future.2014.12.009.
8. Agarwal, S., Kodialam, M., Lakshman, T. V. (2013), "Traffic engineering in software defined networks". *INFOCOM. Proceedings IEEE.* P. 2211–2219.
9. Qureshi, K. N., Abdullah, A. H., Hassan, A. N., Sheet, D. K., Anwar, R. W. (2014), "Mechanism of Multiprotocol Label Switching for Forwarding Packets & Performance in Virtual Private Network". *Middle-East Journal of Scientific Research.* Vol. 20. No. 12. P. 2117–2127.
10. Angrishi, K. (2013), "An end-to-end stochastic network calculus with effective bandwidth and effective capacity". *Computer Networks.* Vol. 57. Issue 1. P. 78–84. DOI: 10.1016/j.comnet.2012.09.003.
11. Hashish, S., Karmouch, A. (2010), "An adaptive rendezvous data dissemination for irregular sensor networks with multiple sinks". *Computer Communications*. 2010. Vol. 33. Issue 2. P. 176–189. DOI: 10.1016/j.comcom.2009.08.013.
12. Olifer, V. G., Olifer, N. A. (2010), *Computer networks. Principles, technologies, protocols*. 4th ed. St. Petersburg : Peter. 943 p.
13. Kosenko, V, Bugas, D (2015), "Development of mathematical models of parameters data flow information and telecommunications network". Eastern-European Journal of Eenterprise Technologies. No. 5/4 (77). P. 37–44.
14. Kuchuk, H. (2013), "Method of corporate multiservice networkcoherent fragment informative structure synthesis". *Scientific Works of Kharkiv National Air Force University*. No. 2. P. 97–102.
15. Kosenko, V, Bolubash, A. (2007), "Routing data streams in multiservice networks" ["Marshrutyzatsiya potokiv danykh u mul tyservisnykh merezhakh"]. *Information Processing Systems*. Ivan Kozhedub Kharkiv National Air Force University. No. 9 (67). P. 94-97.
16. Kuchuk, H., Kosenko, V., Davikoza, A. (2013), "Method of resources allocation of multiserver knot of nformation treatment is control". *Scientific Works of Kharkiv National Air Force University*. No. 3 (36). P. 111–115.

Received 15.09.2017

Відомості про авторів / Сведения об авторах / About the Authors

Косенко Віктор Васильович – кандидат технічних наук, доцент, Державне підприємство "Харківський науково-дослідний інститут технології машинобудування", директор, м. Харків, Україна; e-mail: kosv.v@ukr.ua; ORCID: 0000-0002-4905-8508.

Косенко Виктор Васильевич – кандидат технических наук, доцент, Государственное предприятие "Харьковский научно-исследовательский институт технологии машиностроения", директор, г. Харьков, Украина; e-mail: kosv.v@ukr.ua; ORCID: 0000-0002-4905-8508.

Kosenko Viktor – PhD (Engineering), Associate Professor, State Enterprise "Kharkiv Scientific-Research Institute of Mechanical Engineering Technology", Director, Kharkiv, Ukraine; e-mail: kosv.v@ukr.ua; ORCID: 0000-0002-4905-8508.

Персіянова Олена Юріївна – Державне підприємство "Південний державний проектно-конструкторський та науково-дослідний інститут авіаційної промисловості", інженер, м. Харків, Україна; e-mail: persikqw@gmail.com; ORCID: 0000-0003-3578-4653.

Персиянова Елена Юрьевна – Государственное предприятие "Южный государственный проектно-конструкторский и научно-исследовательский институт авиационной промышленности", инженер, г. Харьков, Украина; e-mail: persikqw@gmail.com; ORCID: 0000-0003-3578-4653.

Persiyanova Elena – State Enterprise "Southern National Design & Research Institute of Aerospace Industries", Engineer, Kharkiv, Ukraine; e-mail: persikqw@gmail.com; ORCID: 0000-0003-3578-4653.

Белоцький Олексій Олександрович – Харківська обласна державна адміністрація, начальник управління паливно-енергетичного комплексу, м. Харків, Україна; e-mail: alexeytek@gmail.com; ORCID: 0000-0003-3716-0852.

Белоцкий Алексей Александрович – Харьковская областная государственная администрация, начальник управления топливно-энергетического комплекса, г. Харьков, Украина; e-mail: alexeytek@gmail.com; ORCID: 0000-0002-4905-8508.

Belotskyy Oleksiy – Kharkiv Regional State Administration, Head of the Department of Fuel and Energy Complex, Kharkiv, Ukraine; e-mail: alexeytek@gmail.com; ORCID: 0000-0002-4905-8508.

Малєєва Ольга Володимирівна – доктор технічних наук, професор, Національний аерокосмічний університет імені М.Є. Жуковського "ХАІ", професор кафедри інформаційні обчислювальні системи, м. Харків, Україна; e-mail: omaleyeva@ukr.net, ORCID: 0000-0002-9336-4182

Малеева Ольга Владимировна – доктор технических наук, профессор, Национальный аэрокосмический университет имени Н.Е. Жуковского "ХАИ", профессор кафедры информационные вычислительные системы, г. Харьков, Украина; e-mail: omaleyeva@ukr.net, ORCID: 0000-0002-9336-4182

Malyeyeva Olga – Doctor of Sciences (Engineering), Professor, National Aerospace University – Kharkiv Aviation Institute, Professor at the Department of Information Computing Systems, Kharkiv, Ukraine; e-mail: omaleyeva@ukr.net, ORCID: 0000-0002-9336-4182.

МЕТОДИ УПРАВЛІННЯ РОЗПОДІЛОМ ТРАФІКУ В ІНФОКОМУНІКАЦІЙНИХ МЕРЕЖАХ СИСТЕМ КРИТИЧНОЇ ІНФРАСТРУКТУРИ

Предметом дослідження в статті є інфокомунікаційні мережі систем критичної інфраструктури. **Мета** роботи – створення методів управління потоками даних та ресурсами ІКМ СКІ для підвищення оперативності обробки інформації. В статті вирішуються наступні **завдання:** формування моделі потоків даних багаторівневої структури ІКМ, розробка методу адаптивного розподілу інформаційних потоків, розробка методу розподілу ресурсів мережі для багатосерверного вузла. Використовуються такі **методи:** методи математичної статистики для випадкових процесів, теорія систем масового обслуговування, методи теорії оптимізації та дослідження операцій. Отримано наступні **результати:** сформульовані принципи управління розподілом мережевого трафіка в ІКМ СКІ та визначено практичні вимоги, що виникають до оперативності передачі даних. Показані можливі підходи до постановки і вирішення перерахованих завдань відповідно до розробленого загального підходу до управління мережею. Досліджена багаторівнева інформаційна структура. Розроблено математичну модель потоків даних багаторівневої інформаційної структури мережі, яка має трирівневу стратифіковану структуру і складається з ряду підмереж та груп вузлів. Розроблено метод адаптивного управління розподілом інформаційних потоків даних, який передбачає стратифіковане дворівневе управління, котре базується на формуванні багатовимірного простору станів мережі та параметрів управління з врахуванням активності користувачів. Управління здійснюється на першому рівні шляхом налагодження базових параметрів мережі, на другому – оперативним управлінням при постійних базових параметрах. Розроблено метод розподілу ресурсів багатосерверного вузла обробки інформації, шляхом того, що системи серверів розглядаються як сукупність однолінійних систем масового обслуговування та використовується інформація щодо розподілу смуги пропускання каналів зв'язку**. Висновки:** Застосування методу адаптивного управління розподілом трафіку дозволяє зменшити час обробки системних транзакцій та сумарну вартість витрат на обслуговування. Застосування методу розподілу ресурсів багато серверного вузла під час реінжинірингу процесів СКІ мінімізує витрати на обслуговування інформаційних потоків.

Ключові слова: інфокомунікаційна мережа, системи критичної інфраструктури, розподіл трафіку, багатосерверний вузол, потоки даних.

МЕТОДЫ УПРАВЛЕНИЯ РАСПРЕДЕЛЕНИЕМ ТРАФИКА В ИНФОКОММУНИКАЦИОННЫХ СЕТЯХ СИСТЕМ КРИТИЧЕСКОЙ ИНФРАСТРУКТУРЫ

Предметом исследования в статье является инфокоммуникационные сети систем критической инфраструктуры. **Цель** работы - создание методов управления потоками данных и ресурсами ИКМ СКИ для повышения оперативности обработки информации. В статье решаются следующие **задачи:** формирование модели потоков данных многоуровневой структуры ИКМ, разработка метода адаптивного распределения информационных потоков, разработка метода распределения ресурсов сети для многосерверных узла. Используются следующие **методы:** методы математической статистики для случайных процессов, теория систем массового обслуживания, методы теории оптимизации и исследования операций. Получены следующие **результаты:** сформулированы принципы управления распределением сетевого трафика в ИКМ СКИ и определены практические требования, возникающие в оперативности передачи данных. Показаны возможные подходы к постановке и решению перечисленных задач в соответствии с разработанным общего подхода к управлению сетью. Исследована многоуровневая информационная структура. Разработана математическая модель потоков данных многоуровневой информационной структуры сети, имеет трехуровневую нестратифицированную структуру и состоит из ряда подсетей и групп узлов. Разработан метод адаптивного управления распределением информационных потоков данных, предусматривающий стратифицировано двухуровневое управление, которое базируется на формировании многомерного пространства состояний сети и параметров управления с учетом активности пользователей. Управление осуществляется на первом уровне путем налаживания базовых параметров сети, на втором - оперативным управлением при постоянных базовых параметрах. Разработан метод распределения ресурсов многосерверного узла обработки информации, путем того, что системы серверов рассматриваются как совокупность однолинейных систем массового обслуживания и используется информация о распределении полосы пропускания каналов связи. **Выводы:** применение метода адаптивного управления распределением трафика позволяет уменьшить время обработки системных транзакций и суммарную стоимость затрат на обслуживание. Применение метода распределения ресурсов серверного узла в ходе реинжиниринга процессов СКИ минимизирует затраты на обслуживание информационных потоков.

Ключевые слова: инфокоммуникационные сеть, системы критической инфраструктуры, распределение трафика, многосерверных узел, потоки данных.