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DEVELOPMENT OF THE METHOD OF INCREASING THE EFFICIENCY OF INFORMATION TRANSFER IN THE SPECIAL PURPOSE NETWORKS

Oleg Sova
Corresponding author
Doctor of Technical Sciences, Senior Researcher, Head of Department
Department of Automated Control Systems*
E-mail: soy_135@ukr.net
Hryhorii Radzivilov
PhD, Associate Professor, Deputy Head of the Institute for Research*
Andrii Shyshatskyi
PhD, Senior Researcher, Senior Research Fellow
Research Department of Electronic Warfare Development**
Dmytro Shevchenko
PhD
Department of Communications
Institute of Troops (Forces) Support and Information Technologies
The National Defence University of Ukraine named after Ivan Cherniakhovskyi
Povitroflotskiy ave., 28, Kyiv, Ukraine, 03049
Bohdan Molodetskyi
PhD, Head of Scientific Research Department
Scientific Research Department
Research Institute of the Ministry of Defense of Ukraine
Yuri Ilyenko str., 81, Kyiv, Ukraine, 04050
Vitalii Stryhun
Senior Researcher
Scientific Research Department of Testing Samples of Weapons and Military Equipment
State Scientific Research Institute of Armament and Military Equipment Testing and Certification
Striletska str., 1, Chernihiv, Ukraine, 14034
Yurii Yivzhenko
PhD, Head of Sector
Sector of Scientific and Educational and Methodological Support for the Training of Professional Junior Bachelors in the System of Professional Pre-Higher Education of the Division of Scientific and Methodological Support of Vocational Education
State Scientific Institution «Institute of Education Content Modernization»
Mytropolyta Vasylia Lypkivskoho str., 36, Kyiv, Ukraine, 03035
Yevhen Stepanenko
PhD, Senior Research Fellow
Scientific Research Centre
Military Institute of Kyiv National University Taras Shevchenko
Lomonosova str., 81, Kyiv, Ukraine, 03189
Nadiia Protas
PhD, Associate Professor
Department of Information Systems and Technologies
Poltava State Agrarian University
Skovorody str., 1/3, Poltava, Ukraine, 36003
Oleksii Nalapko
PhD, Senior Research Fellow
Scientific-Research Laboratory of Automation of Scientific Researches**
*Military Institute of Telecommunications and Information Technologies named after Heroes of Kruty
Moskovsky str., 45/1, Kyiv, Ukraine, 010011
**Central Scientific Research Institute of Armaments and Military Equipment of the Armed Forces of Ukraine
Povitrofloski ave., 28, Kyiv, Ukraine, 03049

The features of modern military conflicts require significantly increasing requirements for the efficiency of determining a rational route for the transmission of information. It is necessary to develop algorithms (methods and techniques) that are able for a limited time and with a high degree of reliability to determine the rational route of information transmission in complex hierarchical information transmission systems. The following tasks were solved in the research: the task of information transfer in special purpose networks was set; the algorithm of realization of a method of efficiency increase of information transfer is defined; simulation of the process of information transfer in the communication networks of a group of troops (forces) was carried out. The essence of the proposed method is to use the ant algorithm and their further training.

The method has the following sequence of actions: input of initial data; determining the degree of uncertainty and noise of the original data, determining the set of acceptable solutions, determining belonging to a certain class. The next step is to determine the route of information transfer, taking into account the impact of destabilizing factors, taking into account computing power and training ants.

The novelty of the method is to take into account the type of uncertainty and noise in the data and take into account the available computing resources of the communication network. The novelty of the method also lies in the use of advanced training procedures using the apparatus of evolving artificial neural networks and selective use of system resources by connecting only the required number of agents (ants).

The method allows to build a rational route of information transfer taking into account the influence of destabilizing factors. The use of the method allows to achieve an increase in the efficiency of information transfer at the level of 11–16 % through the use of additional advanced procedures

Keywords: special purpose transmission systems, efficiency of information processing, computing power of the system

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1. Introduction

The growth of information circulating in various systems of collection, processing and transmission of information leads to significant use of computing resources of hardware. The armed forces of technically developed countries have integrated decision-making architectures based on:

– artificial intelligence and nanotechnology;

– efficient processing of large arrays of information;

– multifunctional processors with the ability to support real-time decision making;

– data compression technologies to increase their processing speed.

At the same time, the use of information systems with elements of artificial intelligence will increase the effectiveness of operations (combat operations), will affect the doctrine, organization and methods of using groups of troops (forces).

However, increasing the dynamism of operations, increasing the number of devices of information transmission, options for destructive effects on special purpose information transmission systems creates a number of problems [1–8]:

– the use of a large amount of false information in order to mislead the warring parties;

– forms of information presentation complicate its transmission through communication channels;

– limited computing power of hardware and bandwidth of data transmission channels;

– the increase of the number of options for destructive impact on communication systems;

– the need to increase the number of indicators that assess the state of the communication system;

– hierarchy and multidimensionality of information transmission systems;

– the transition to the principle of evaluation of the communication system «everything affects everything at once», which covers the aggregate network and computing resources of all types of armed forces.

The above indicates that the solution to the problem of information transmission in special purpose communication networks is reduced to a class of NP-complex calculations. Large-scale problems often remain unsolved due to the large number of iterations and the complexity of the calculations. Recently, close attention has been paid to the behavior of living beings and processes that occur in nature. This is used as an idea while creating methods and algorithms for solving optimization problems, on the example of which optimal or close to optimal solutions are obtained. However, ant algorithms have shown reliability in solving problems of information transmission in hierarchical and multidimensional information transmission systems. Ant optimization algorithms belong to the class of approximate probabilistic algorithms. Obtaining a solution is called an iteration. Since several agents, artificial ants, work at the same time, let's get as many valid solutions for one iteration as the ants did the work. The process of obtaining a valid solution is represented as its direct layout. At each step, one component of the decision vector is specified.

Mathematical representation of multiplicity in known ant algorithms is realized by independently solving the problem by several agents (ants) separately, independently of each other.

Given the above, the urgent scientific task is to develop a method to increase the efficiency of information transmission in special purpose communication networks.

2. Literature review and problem statement

The use of the method of consistent decision-making to increase the efficiency of decision-making was proposed in the works [4, 5]. In deterministic algorithms, the number of concretized components is selected differently. For example, in greedy algorithms – according to the magnitude of the components of the value vector. Priority is given to the component that will make the largest (smallest) contribution to the target value of the function [6]. In genetic-type algorithms, the order of concretization is determined by the frequency of the positive value of the component in some of the best solutions [4]. In works [7, 8] the combined approach of assignment of a priority of a component is resulted. Any additional work on the ordering of the components of the decision vector makes a positive contribution to the assessment of the rate of convergence of combinatorial algorithms. The very idea of ordering the components appeared a long time ago. Balash algorithm, which represents the method of branches and boundaries with one-sided branching, used this as the main approach in the partial search of options. In the methods of branches and boundaries with two-sided branching, the idea of the Balash algorithm has been used repeatedly, resulting in good results [8].

In ant algorithms, the number of the specified component at each step of the algorithm is selected randomly, in proportion to the probability. The quantitative value of the probability depends on the parameters α and β. In other words, it depends on the accumulation of pheromones and their evaporation. In the work [3], it was experimentally shown that the magnitude of the error of the approximate solution depends on β. This work continues the research on improving combinatorial algorithms and is devoted to the development of an ant colony algorithm for solving a multidimensional backpack problem.

Cognitive modeling algorithm is presented in the work [9]. The main advantages of cognitive tools are determined. The disadvantages of this approach include the lack of consideration of the uncertainty type about the analysis object state.

The essence of cognitive modeling and scenario planning is revealed in the work [10]. The system of complementary principles of construction and realization of scenarios is offered, different approaches to construction of scenarios are allocated, the procedure of modeling of scenarios on the basis of indistinct cognitive maps is described. The approach proposed by the authors does not take into account the type of uncertainty about the analysis object state and does not take into account the noise of the initial data.

In the work [11], the analysis of the main approaches to cognitive modeling is carried out. Cognitive analysis allows to: investigate problems with fuzzy factors and relationships; take into account changes in the external environment and use objectively formed trends in the interests of the situation. However, in this paper the question of describing complex and dynamic processes remains unexplored.

In the work [12] the method of analysis of large data sets is presented. This method is focused on finding hidden information in large data sets. The method includes operations of generating analytical baselines, reducing variables, detecting sparse features and specifying rules. The disadvantages of this method include the inability to take into account different strategies for evaluating decisions, the lack of consideration of the uncertainty type of the input data.

In the work [13], the mechanism of transformation of information models of construction objects to their equivalent structural models is given. This mechanism is designed to automate the necessary operations of transformation, modification and addition during such an exchange of information. The disadvantages of this approach include the inability to assess the adequacy and reliability of the process of information transformation and to make appropriate adjustments to the resulting models.

In the article [14], the development of an analytical web-platform for the research of geographical and temporal distribution of incidents. Web-platform, contains several information panels with statistically significant results by territory. The disadvantages of this analytical platform include the inability to assess the adequacy and reliability of the process of information transformation and high computational complexity. Also, the disadvantages of this research should not include one-way search for a solution.

In the work [15], the method of fuzzy hierarchical assessment of the quality of library services was developed. This method allows to evaluate the quality of libraries on a variety of input parameters. The disadvantages of this method include the inability to assess the adequacy and reliability of the assessment and, accordingly, to determine the error of assessment.

In the work [16], an analysis of 30 algorithms for processing large data sets was performed. Their advantages and disadvantages are shown. It is established that the analysis of large data sets should be carried out in layers, in real time and have the opportunity for self-study. The disadvantages of these methods include their high computational complexity and the inability to verify the adequacy of the estimates.

In the work [17], the approach of estimation of input data for decision making support systems is presented. The essence of the proposed approach is to cluster the basic set of input data, their analysis, and then on the basis of the analysis is learning the system. The disadvantages of this approach are the gradual accumulation of evaluation and learning errors due to the lack of ability to assess the adequacy of decisions.

In the work [18], the approach to data processing from different sources of information is presented. This approach allows data processing from various sources. The disadvantages of this approach include the low accuracy of the estimate and the inability to verify the reliability of the estimate.

In the work [19], a comparative analysis of existing decision making support technologies, namely: the method of analysis of hierarchies, neural networks, fuzzy set theory, genetic algorithms and neuro-fuzzy modeling. The advantages and disadvantages of these approaches are indicated. The spheres of their application are determined. It has been shown that the method of hierarchy analysis works well with complete initial information, but due to the need for experts to compare alternatives and choose evaluation criteria, it has a high share of subjectivity. The use of fuzzy set theory and neural networks is justified for forecasting problems in conditions of risk and uncertainty.

In the work [20], a method of structural-target analysis of the development of poorly structured systems was developed. Approach to the research of conflict situations caused by contradictions in the interests of the subjects that affect the development of the studied system and methods of solving poorly structured problems based on the formation of scenarios. The problem is defined as the mismatch of the existing state of the system to the required, which is set by the subject of management. However, the disadvantages of the proposed method include the problem of local optimum and the inability to conduct a parallel search.

The analysis of works [9–21] showed that the common shortcomings of the above researches are:

– not taking into account the impact of destabilizing factors that affect the efficiency of special purpose networks;

– existing methods of information transfer are intended for civilian networks, which does not allow their use for special purpose systems;

– the variety of information circulating in special purpose networks;

– the lack of possibility to form a hierarchical system of indicators for assessing the state of special purpose networks;

– the lack of consideration of computing resources of communication networks;

– the lack of mechanisms for deep learning of knowledge bases;

– the lack of consideration of available computing resources.

For this aim, it is proposed to develop a method to increase the efficiency of information transmission in special purpose networks.

3. The aim and objectives of the research

The aim of the research is to develop a method to increase the efficiency of information transmission in special purpose networks with a given reliability. This will increase the efficiency of information transfer in special purpose networks.

To achieve this goal, the following tasks were set:

– to set the task of transmitting information in special purpose networks;

– to determine the algorithm for implementing the method of increasing the efficiency of information transfer;

– to model the process of information transfer in the communication systems of a group of troops (forces).

4. Materials and methods of research

In the course of the research the general provisions of the theory of artificial intelligence were used to solve the problem of analysis of special purpose networks and to determine the route of information transmission. Thus, the theory of artificial intelligence is the basis of this research. The research used an ant algorithm and evolving artificial neural networks. The simulation was performed using MathCad 2014 software (USA) and Intel Core i3 PC (USA).

5. Research results on the development of a method to increase the efficiency of information transfer in special purpose networks

5. 1. Setting the task of transmitting information in special purpose networks

Let's suppose that there is a mathematical model of a multidimensional backpack problem:

$$z=\left(\left(\max\sum_{j=1}^{n}c_jx_j\right)\times\zeta_{ij}\right)\times\iota_{ij},$$

$$\sum_{j=1}^{n}\alpha_{ij}x_j\le b_i,\ \ i=\overline{1,m},$$

$$x_j\in\{0,1\},\ \ j=\overline{1,n}, \tag{1}$$

where n is the number of values $(j=\overline{1,n})$ to be found. This refers to the parametric assessment of the traffic type, traffic intensity and destructive impact. Destructive influence means intentional interference, signal fading during multibeam propagation of radio waves, cyber attacks on the communication system and fire damage;

m is the number of restrictions $(i=\overline{1,m})$, under the restrictions means the hardware and software limitations of the transceivers of the communication system, devices of radioelectronic suppression, cyber impact and devices of fire destruction;

r is the number of agents $(k=\overline{1,r})$ simultaneously and independently of each other, which determine the valid solutions. In this case let's mean those ants that are the part of this algorithm and their species;

$\alpha_{\min}$ is the parameter, threshold value of the pheromone;

β is the pheromone evaporation coefficient. The specified parameter regulates the lifespan of the route (its lifetime);

T is the number of iterations of the algorithm $(t=\overline{1,T})$ that is set in advance;

γ_j is the number of valid solutions in which the γ-th component is specified by a value of 1 on a specific iteration. This parameter characterizes the computational complexity of the algorithm;

V_j^k is the set of indices for the j-th admissible solution such that x_j can be specified by the value «1» while performing the next iteration;

p_j^k is the probability of choosing the x-th component for concretization in the k-th solution;

I^k is the set of indices of the specified components in the k-th solution;

ι_{ij} is the operator that takes into account the level of awareness of the state of the special purpose communication system;

ζ_{ij} is the operator to take into account the noise level of the special purpose communication system data.

After the iteration, the presence of pheromones is listed for each k-th component according to the formula:

$$a_j = \frac{a_{\min} + \dfrac{\gamma_j}{n}\left(\alpha_j - \alpha_{\min}\right)}{\beta}. \quad (2)$$

At each iteration step, the set V_j^k for each ant is determined as follows:

$$V_j^k = \left\{ j \left| \left(b_i^k - \sum_{j\in I^k} a_{ij} \right) \geq 0, i=\overline{1,m} \right. \right\},\ k=\overline{1,r}. \quad (3)$$

The probability of choosing the component x_j to be specified is calculated by the following probability-proportional rule:

$$p_j^k = \frac{a_j\left(c_j - c_{\min}\right)}{\sum_{j\in V_j^k} a_j\left(c_j - c_{\min}\right)},\ j\in V_j^k,\ k=\overline{1,r},$$

$$X^k = \left(x_1^k, x_2^k, \ldots, x_n^k\right), \quad (4)$$

where $c_{\min} = \min_{j\in V_j^k} c_j - 1$.

At each iteration, according to rule (3), the magnitude of the probability is determined. According to its value, the component to be specified is selected. The choice is random. To do this, the value of the uniformly distributed random variable from the interval (0,1) is generated. Hitting it in the appropriate interval in proportion to the probability is determined by the number of specified components.

The admissible solution for each ant is considered to be obtained if $V_j^k = 0,\ (k=\overline{1,r})$. After obtaining all r admissible solutions $X^k = (x_1^k, x_2^k, \ldots, x_n^k)$ the value of γ_j is calculated:

$$\gamma_j = \sum_{k=1}^{r} x_j^k,\ j=\overline{1,n}. \quad (5)$$

Then the iteration t $(t>2)$ is repeated with new values of α_j by formula (1). For the first iteration, all α_j are accepted, defined as identical and of some value q_0 $(q_0 \in (0,1))$.

Expression (1) allows to form a description of the process of information transfer taking into account the influence of destabilizing factors. This description is universal and allows to describe the transmission of information in special purpose networks for each type of information transmission systems. Expression (1) while constructing a mathematical description of the process of information transfer takes into account the degree of awareness of the destructive effects and noise of the data.

5. 2. Development of an algorithm for implementing a method to increase the efficiency of information transfer

The following sequence of actions is offered as a basis of a method of increase of efficiency of information transfer.

Step 1. Enter the source data.

At this stage, the initial data about the state of the communication network is entered. The number of sources of technical devices of monitoring, type of initial data and their volume are determined. Enter the values of the parameters β, $\alpha_{\min}$, the number of agents $r1$, the number of iterations T.

Step 2. Determine the degree of uncertainty about the state of the network.

It takes into account the uncertainty of information about the state of the network, namely: full awareness, partial uncertainty and complete uncertainty.

Step 3. Set the following parameter values: $ZM=0, \alpha_j = q_0$, $j=\overline{1,n},\ t=1$.

Step 4. Prepare arrays $X^k = (x_1^k, x_2^k, \ldots, x_n^k), k=\overline{1,r}, I^k, r=r1$.

Step 5. Define sets $V_j^k,\ k=\overline{1,r}$.

Step 6. Determine the available hardware computing resources.

At this stage, the available hardware computing resources of the network are determined. Based on this, possible classification options are determined: binary classification tree, genetic algorithm, fuzzy cognitive models and acyclic graph.

In the Table 1 shows the characteristics of the considered schemes of combining detectors into a multi-class model, designed to correlate the input object of one or more of the $(m+1)$ labels of classes.

Table 1

Characteristics of detector integration schemes

Merger scheme	Number of detectors to be trained	Minimum number of detectors involved in object classification	Maximum number of detectors involved in object classification
One-to-all	m	m	m
One-to-one	$\frac{(m+1)\cdot m}{2}$	$\frac{(m+1)\cdot m}{2}$	$\frac{(m+1)\cdot m}{2}$
Classification binary tree	m	1	m
Directed acyclic graph	$\frac{(m+1)\cdot m}{2}$	m	m
Fuzzy cognitive model	$(m{*}x){*}m$	$(m{*}x)$	$(m{*}x){*}m$
Any algorithm	$(m{*}x)$	m	$(m{*}x)$

Step 7. Identify destabilizing factors affecting the communication network. The classification binary tree can be mentioned as one of the derivative variations of the previous

approaches for combining detectors [22–26]. Formally, this structure is set recursively as follows:

$$CBT_\mu = \begin{cases} \left\langle F^{(i)}_{jL_\mu R_\mu}, CBT_{L_\mu}, CBT_{R_\mu} \right\rangle, \text{ if } \#\mu \geq 2, \\ \mu, \qquad\qquad\qquad\qquad \text{if } \#\mu = 1, \end{cases} \tag{6}$$

where $\mu=\{0,...,m\}$ is the original set of class labels, $L_\mu \subsetneq \mu$ is the arbitrarily generated or defined subset; $\mu\left(\#L_\mu < \#\mu\right)$, $R_\mu=\mu \setminus L_\mu$ is left classification subtree, CBT_{R_μ} is right classification subtree, $F^{(i)}_{jL_\mu R_\mu}$ is the node detector, trained on the elements of the set $\{(x_l,0) | \overline{c}_l \in L_\mu\}^M_{l=1} \cup \{x_l,1 | \overline{c}_l \in R_\mu\}^M_{l=1}$.

The output of the detector is set to 0 if the input object x_l belongs to a class with a label $\overline{c}_l \in L_\mu$, and 1 if the object x_l belongs to a class with a label $\overline{c}_l \in L_\mu$.

Therefore, the operation of a group of detectors $F^{(i)}_j$, presented in the form of nodes of such a tree is described by a recursive function $\varphi^{(i)}_j$, that specifies the sequential dichotomy of the set μ:

$$F^{(i)}_j = \varphi^{(i)}_j(\mu, z),$$

$$\varphi^{(i)}_j(\mu, z) = \begin{cases} \mu, \qquad \text{if } \#\mu=1, \\ \varphi^{(i)}_j\left(L_\mu, z\right) \text{ if } \#\mu \geq 2 \wedge F^{(i)}_{jL_\mu R_\mu}(z) = 0, \\ \varphi^{(i)}_j\left(R_\mu, z\right) \text{ if } \#\mu \geq 2 \wedge F^{(i)}_{jL_\mu R_\mu}(z) = 1. \end{cases} \tag{7}$$

Applying the function $\varphi^{(i)}_j$ to the original set of class labels and the network allows to uniquely search for the class label of this network. This is because as to go down the classification tree, many class labels are disjunctively broken. Once the terminal detector is reached and triggered, there is only one possible label left for classifying the input object z as the output result $F^{(i)}_j$. Therefore, conflicts are not possible for the classification tree while classifying objects that may occur for the other two combining approaches [26–30].

Another approach is a directional acyclic graph, which organizes $C^2_{m+1} = (m+1)\cdot m/2$ detectors into a coherent dynamic structure, which can be given by the following formula:

$$DAG_\mu = \begin{cases} \left\langle F^{(i)}_{j\mu k_0 k_1}, DAG_{\mu\setminus\{k_0\}}, DAG_{\mu\setminus\{k_1\}} \right\rangle, \\ \text{if } \#\mu \geq 2, \text{ where } k_0 \in \mu, k_1 \in \mu, \\ \mu, \text{ if } \#\mu = 1. \end{cases} \tag{8}$$

The minimum value is reached when the detector $F^{(i)}_{jL_\mu R_\mu}$, located at the root of the tree is activated and trained to recognize only one class of destabilizing effects among all others, and $F^{(i)}_{jL_\mu R_\mu}(z)=0$ ($F^{(i)}_{jL_\mu R_\mu}(z)=1$) when $\#L_\mu=1$ ($\#R=1$). The maximum value is reached when the tree is represented by a sequential list and the most remote detector is activated.

In the case of a balanced tree, this figure can be a value $\lfloor \log_2(m+1) \rfloor$ or $\lceil \log_2(m+1) \rceil$. Each classifier $F^{(i)}$ ($i=1,...,P$) contains q_i groups $F^{(i)}_j\left(j=1,...,q_i\right)$, each of which combines m detectors $F_{jk}^{(i)}$ ($k=1,...,m$) using a one-to-all approach. Each of the groups of detectors $F^{(i)}_j$ is trained in different random samples, which may include repetitive and rearranged elements from the original training set $\Upsilon_{\chi^{(LS)}_c}$. The groups $F_j^{(i)}$ are grouped into classifier $F^{(i)}$ on the basis of a hybrid rule, which is a mixture of majority voting and max-wins voting:

$$F^{(i)}(z) = \left\{ \begin{matrix} \overline{c} | \underbrace{\sum_{j=1}^{q_i}\left[\overline{c} \in F^{(i)}_j(z)\right]}_{\Xi_i(\overline{c})} > \dfrac{1}{2}\cdot q_i \wedge \\ \wedge \Xi_i(\overline{c}) = \max\limits_{\overline{c}' \in \{0,...,m\}} \Xi_i(\overline{c}') \end{matrix} \right\}^m_{\overline{c}'=0}. \tag{9}$$

In this formula, due to the requirement $\Xi_i(\overline{c}) > 1/2 \cdot q_i$, the classifier $F^{(i)}$ becomes incapable of resolving conflicts that arise under the condition:

$$\#\left\{ \overline{c} \middle| \Xi_i(\overline{c}) = \frac{1}{2}\cdot q_i \wedge \Xi_i(\overline{c}) = \max_{\overline{c}' \in \{0,...,m\}} \Xi_i(\overline{c}') \right\}^m_{\overline{c}'=0} = 2$$

(in this case, the output of the classifier is an empty set $\varnothing$).

During the operation of the interpreter, the correctness of the processed data is checked and the fields of the objects inside the classifier tree are initialized [31–35].

Step 8. If there is a set $V^{k_0}_j = 0$, go to step 15.

Step 9. Identify p^k_j, $j=\overline{1,n}$, $k=\overline{1,r}$.

Step 10. In accordance with p^k_j and on the basis V^k_j of the components $x^k_{j_0}$, to be specified value «1», to $k=\overline{1,r}$.

Step 11. Define $x^k_{j_0}=1$, $k=\overline{1,r}$, and the set $I^k = I^k \cup x^k_{j_0}$, $k=\overline{1,r}$.

Step 12. Determine the value of the pair γ_j, $j=\overline{1,n}$.

Step 13. Define new values α_j, $j=\overline{1,n}$.

Step 14. Go to step 6.

Step 15. $r=r-1$; calculate the value of the obtained admissible solution z_{k_0}.

Step 16. *If* $r=0$, then return to step 17.

Step 17. Go to Step 6.

Step 18. $r=r1$, $z_{k_0} = \max_{k=\overline{1,r}} Z_k$, $X = X^{k_0}$.

Step 19. If $z_{k0} < ZM$, then go to step 20.

Step 20. $z_{k0}=ZM$, $XM=X^{k0}$.

Step 21. Go to the next iteration.

Step 22. $t<T$ then return to step 5.

Completion of the algorithm.

5. 3. Example of modeling the process of information transfer in communication systems of a group of troops (forces)

To assess the effectiveness of the proposed method, simulation of the radio communication devices (RCD) with frequency-hopping spread spectrum (FHSS) at different degrees of deliberate interference acting on the communication channel. The simulation was performed in the MathCad 14 software environment using the mathematical relations obtained above. The communication network is 16 RCD with FHSS. Simulations were performed with the following parameters:

– devices of radio communication with FHSS: frequency range is 30–512 MHz; transmitter power is 10 W; the bandwidth of the emitted frequency band is 12.5 kHz, the sensitivity of the receiver is 110 dB; the number of RCD in the network is 4; number of frequency channels for reconfiguration is 10,000; the amount of adjustment is 333, 5 jumps/sec;

– radio electronic suppression complex: frequency range is 30–2,000 MHz; transmitter power is 2,000 W; the maximum frequency that can be suppressed is 80 MHz; the number of radio lines with FHSS that can be suppressed at the same time is 4, the type of interference is noise obstruction with frequency manipulation; the strategy of the RES complex is dynamic.

To test the effectiveness of the proposed method, let's assume that the operating time of the RCD with FHSS on the same frequency is the same as the RES complex.

Fig. 1 shows a graph of the dependence of the probability of bit error on the signal-to-noise ratio (for the case of noise interference in the part of the band with frequency manipulation $\rho=1$).

As can be seen from Fig. 1, the RES device it is not able to carry out guaranteed suppression of radio communication devices with the FHSS using the specified method.

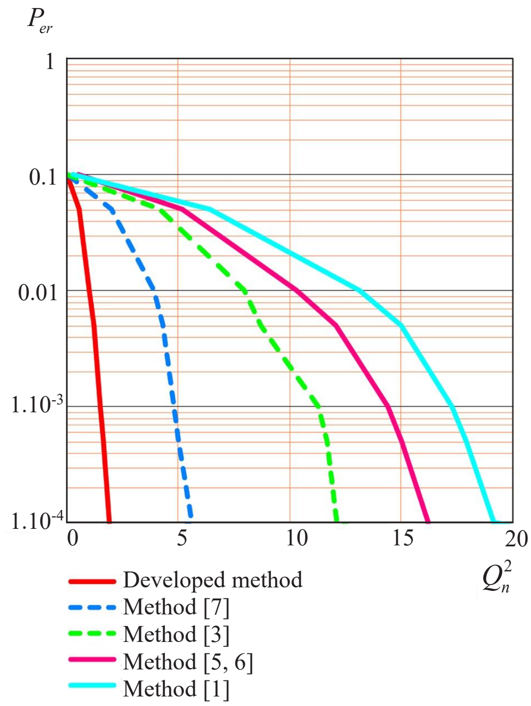

Fig. 1. The dependence of the probability of bit error on the signal-to-noise ratio at for different techniques under the influence of fluctuating noise and noise barrier (ρ = 1)

Fig. 2 shows a graph of the frequency of obtaining the optimal solution for choosing the route of information transmission depending on the number of ants.

The simulation showed the following:

1. The value of the parameters β determines the frequency of optimal or good solution among the allowable solutions obtained by different ants. Fig. 2 shows a graph of the frequency of good decisions on the number of ants and β values.
2. The optimal solution for small problems was within 10 iterations.
3. The approximate solution with a deviation of not more than 1 % or 2 %, was obtained quite often.
4. In the process of performing iterations, the following moment is observed. For some task of choosing the route of information transmission, the optimal (best) solution was repeated many times after its first appearance on an iteration. These statistics are given in Table 2.
5. Elite ants, which repeatedly determine the best solutions, did not stand out.
6. It should be noted that the more ants involved in the generation of acceptable solutions, the greater their scatter in the selection of the best values of the objective function.
7. For large-scale problems of choosing the route of information transmission, the optimal solution of the ant algorithm could not be obtained.

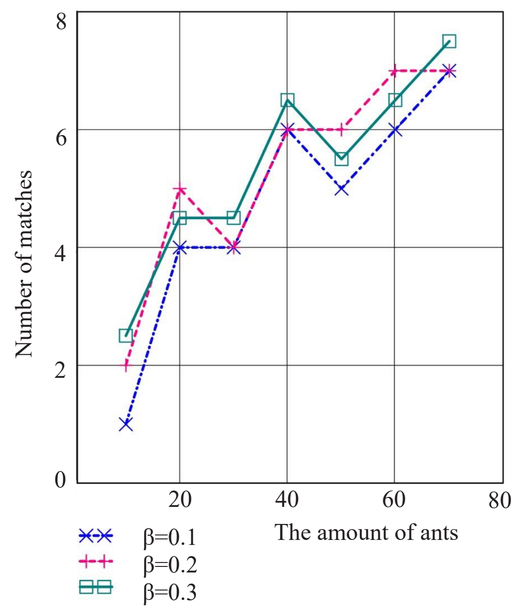

Fig. 2. Graph of the dependence of the frequency of optimal decisions on the choice of information transmission route on the number of ants and β values

The research showed that the use of the method allows to increase the efficiency of information transfer at the level of 11–16 % through the use of additional advanced procedures.

6. Discussion of the results of the development of a method to increase the efficiency of information transfer in special purpose networks

It is established that the developed method has a higher computational complexity at the level of 5–7 %, compared to others, but allows to increase the efficiency of information transfer by 11–16 %, which is acceptable. This is due to the fact that this technique contains additional procedures for calculating the determination of the impact of destabilizing factors on the communication network.

Table 2

Statistics of the emergence of the right decisions

Routes / Ants	β=0.1										β=0.3									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
10	1	0	0	0	0	13	0	0	0	0	13	0	13	13	0	8	7	0	0	0
20	15	2	0	15	6	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0
30	14	4	4	2	0	0	14	0	0	14	3	0	0	0	3	0	0	0	11	14
40	3	3	0	0	3	1	0	1	0	4	1	0	3	3	3	0	2	0	0	4
50	0	2	1	0	1	0	1	7	0	0	0	0	0	5	0	0	4	1	0	0
60	1	0	4	0	2	0	14	1	2	0	0	0	0	2	3	0	2	0	0	0
70	3	0	0	0	4	0	0	1	0	2	1	0	1	1	0	0	5	12	1	2

The main advantages of the proposed method are:

– increasing the efficiency of radio frequency resource use;

– the possibility of RCD operation in conditions of frequency band deficit;

– wide scope of use (civil and special use radio communication systems);

– the ability to adapt to the signal environment of the communication network;

– taking into account the impact of the main types of destabilizing factors;

– the ability to work at low signal/noise ratios in the channel;

– the ability to choose rational routes for information transfer.

The proposed technique allows to increase the efficiency of determining the route of information transfer, taking into account a significant number of destabilizing factors.

The disadvantages of the proposed method include:

– increase of computational complexity at the level of 10 %, which is associated with an increase in the number of procedures;

– under the influence of destabilizing factors on the communication network for some time there will be no exchange of information in the network. The specified time will depend on;

– this technique should not be used in radio communication systems with FHSS with a small number of correspondents in the network and in radio directions.

The method proposed in this paper should be used in the development of software for modules (blocks) for the assessment of promising means of radio communication, based on the open architecture interfaces of version SCA 2.2, which will allow:

– to determine rational routes of information transfer under the influence of destabilizing factors;

– to ensure the efficient use of the radio frequency resource of programmable devices of radio communication;

– to increase the speed of evaluation of communication channels;

– to reduce the use of computing resources of radio communication facilities with programmable architecture.

These methods should be used in radio stations with a programmable architecture that operates under conditions of active electronic suppression. This method will allow:

– to identify the structure of the obstacle, its type and the law of production;

– to assess the state of the radio communication network;

– to ensure the efficient use of the radio frequency resource of programmable devices of radio communication;

– to ensure the effective use of radio communication devices in the network;

– to develop measures aimed at increasing noise immunity.

Limitations of the research should be considered:

– the need to know the electronic environment of the region of application;

– this method should not be used for networks with a small number of nodes;

– the need to adapt special software for its implementation and the minimum hardware resources to ensure sustainable operation.

The method proposed in this paper should be used in the development of software for modules (blocks) for the assessment of advanced radio communication devices, based on the open architecture interfaces of SCA version 2.2.

This research is a further development of research aimed at developing methodological principles of operational management of radio resources of radio communication systems.

7. Conclusions

1. The task of transmitting information in special purpose networks, which is flexible and universal. As a criterion for the effectiveness of this method, the efficiency of the information transfer process with a given reliability of the obtained estimate is chosen. The proposed formulation allows to describe the process of information transfer for any structure of the special purpose network, taking into account destabilizing factors. As a criterion for the effectiveness of this method, it is proposed to use the efficiency of information transfer between the elements of the special purpose network.

2. The algorithm of realization of a method of information transfer efficiency increase that allows:

– to take into account the type of uncertainty and noise of data;

– to take into account the available computing resources of the communication network status analysis system;

– to carry out accurate training of detectors due to the use of an advanced method of training based on evolving artificial neural networks [2]);

– to selective use of system resources by connecting only the necessary types of detectors.

3. An example of the use of the proposed method on the example of the transfer of information between the elements of the communication network of a group of troops (forces). This example showed an increase in the efficiency of data processing efficiency at the level of 11–16 % through the use of additional advanced procedures.

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