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Article

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DEVELOPMENT OF FORCE AND COMMUNICATION MANAGEMENT METHODOLOGY USING RESOURCE OPTIMIZATION METHODS IN MILITARY (FORCE) OPERATIONS

The most characteristic features of the construction of communication systems of groups of troops (forces) during the conduct of hostilities (operations) are a high level of a priori uncertainty regarding the operational situation and a small amount of initial data for communication planning. In such conditions, it is important to correctly choose the apparatus for evaluating the made management decisions, which will allow the officials of the points of the control system of the communication system of the groups of troops (forces) to be confident in the made decisions. That is why the issue of increasing the effectiveness of the management of forces and devices of communication of groups of troops (forces) during operations is an important and urgent issue. The object of the research is the communication system of the group of troops (forces). The subject of the research is the effectiveness of the communication system of the grouping of troops (forces) in accordance with the purpose of the operation. The research developed a method for managing forces and devices of communication using methods of resource optimization in the operations of troops (forces). The novelty of the proposed method consists in taking into account the type of uncertainty regarding the operational situation in the operational space. Also, taking into account the number of members of the grouping (consumers of communication services) of groups of troops (forces) in operations. The novelty of the developed method consists in taking into account the duration of the operation (fighting) and the calculation of the labor costs necessary to meet the needs of the communication services of groups of troops (forces) while planning measures for the distribution and use of forces and devices of communication. The specified method is proposed to be implemented:

– in planning documents during planning the deployment and operation of forces and devices of communication;
– in the software during operational management of the communication system of troop groups.

Keywords: *forces and devices of communication, radio-electronic situation, group of troops (forces), operational management.*

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1. Introduction

The most characteristic features of the construction of special purpose communication systems of groups of troops (forces) during the conduct of hostilities (operations) are a high degree of a priori uncertainty regarding the operational situation and a small amount of initial data for communication planning.

In such conditions, it is important to correctly choose the apparatus for evaluating the made management decisions, which will allow the officials of the points of the control system of the communication system of the groups of troops (forces) to be confident in the decisions being made [1–3].

Making a decision to build a communication system of any level during operations (combat operations), as a rule, includes determining the purpose of its functioning, choosing indicators and justifying evaluation criteria, synthesis of alternative structures and the search for a rational variant of the deployment of the communication system [4–7].

The work [8] defined the tendency to create unified platforms of radio frequency and digital signal processing hardware for joint solution of communication and radar tasks. At the same time, the specified work does not provide specific mechanisms for managing the parameters of GSM standard communication networks for airspace monitoring.

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The work [9] substantiated the reasons for increasing the efficiency of the trunking communication systems of Ukraine. At the same time, the specified type of radio communication devices is not resistant to the influence of devices of radio electronic suppression.

The work [10] developed ways of increasing the efficiency of the use of radio frequency resources in cognitive radio networks. At the same time, the mentioned work does not consider the influence of the location of electronic warfare equipment on the quality of communication in the radio network.

The work [11] proposed a dynamic channel selection algorithm based on the fuzzy inference system (FIS), which is able to select the most available channel with the desired bandwidth, the minimum required signal-to-noise ratio and the probability of detection of a miss. The shortcomings of the proposed algorithm include not taking into account the influence of intentional interference.

The work [12] developed the radio resource access controller based on a sliding window. At the same time, the specified controller does not allow to take into account destabilizing factors present in radio communication channels, such as intentional interference and fading.

The work [13] proposed a method for monitoring the radio frequency spectrum and network architecture to regulate spectrum distribution and control the use of the radio frequency spectrum. At the same time, the proposed approach does not allow to take measures aimed at improving the immunity of military radio networks.

The work [14] proposed an algorithm for controlling the parameters of cognitive radio networks, namely: optimal power, optimal speed and optimal amount of information. This control is based on a genetic algorithm. However, the proposed algorithm takes into account only mutual interference caused by the mutual influence of users on each other.

As the experience of communication organization in operations (during hostilities) shows, the decision regarding the order of communication organization, involvement of forces and devices necessary to meet the needs of communication services indicates:

- the need to have a mathematical apparatus that will allow taking into account the volume of operational tasks for the organization of communication of groups of troops (forces);
- taking into account the numerical composition of the group (consumers of communication services) of groups of troops (forces);
- the duration of the operation (conduct of hostilities) and the labor costs necessary to meet the needs of communication services of groups of troops (forces).

Taking into account the above, *the aim of the research* is to develop a method for managing forces and devices of communication using methods of resource optimization.

The object of research is the communication system of a group of troops (forces).

The subject of research is the effectiveness of the communication system of the group of troops (forces) in accordance with the purpose of the operation.

2. Materials and Methods

In the course of the conducted research, classical methods of analysis were used to solve the problem of analyzing the conditions and factors affecting the communication system of a group of troops (forces) and resource optimization for making managerial decisions on the management of the communication system of a group of troops (forces).

3. Results and Discussion

3.1. Development of methods for managing forces and devices of communication using methods of resource optimization. Let's consider the adaptation (development) of mathematical methods for the effective solution of optimization problems of organizational management of forces and devices of communication.

Problematic scientific tasks of increasing the effectiveness of organizational management of forces and devices of communication, as typical tasks of resource optimization, require the correct selection (adaptation) of existing or the development of effective special methods of the theory of optimal solutions. As a rule, the main tasks of organizational management of troops (forces), as typical tasks of resource optimization (distribution of devices by objects and forces by tasks, selection of the optimal route, «transport problem», etc.), are solved by iterative procedures for improving the initial approximation for the desired solution. Therefore, for the development of these methods, the principle of «maximum dynamic efficiency» of the current solution was developed, which maximizes the efficiency of optimization methods.

«Dynamic efficiency» (DE) of the current (at each iteration) solution is calculated as the ratio of the current values of the «expected» change in the objective function («target effect») and the conditional change in the component of the argument («cost» for its achievement):

$$\varepsilon(x)=\delta w(x)/\delta r(x). \qquad (1)$$

The component of the current solution x_s from their set $\{x\}$ that satisfies the «maximum» criterion of the current DE changes «unconditionally»:

$$\varepsilon(x_s)=\max_{\{x\}}\varepsilon(x). \qquad (2)$$

This principle of «maximum DE» is the content of the corresponding «adaptation» of classical methods of mathematical programming (linear and nonlinear discrete programming with vector and matrix arguments). This requires algorithmic improvement of the bank of procedures of special mathematical software for computer tools for solving scientific research problems.

Let's consider them in more detail. If a certain task of operations research is formalized in the form of a suitability criterion:

$$\forall X=\left\langle x_j, j=\overline{1,n}\right\rangle,\ X\subset\{X\}_i:$$
$$\exists X^o=\left\langle x_j^o, j=\overline{1,n}\right\rangle,\ X^o\subset\{X\}_i. \qquad (3)$$

And also in the form of an optimality criterion:

$$\sum_{j=1}^{n} a_{ij}x_j(\le,\ge)b_i,\ i=\overline{1,m};$$
$$L(X^o)=\sum_{j=1}^{n} c_j x_j^o=\underset{\{X\}}{extr}\,L(X), \qquad (4)$$

then it is a linear programming problem with a vector argument.

The principle of «dynamic efficiency» to improve the current solution requires the calculation of acceptable values of a set of variables at each iteration:

$$x_j = \min_{i=1,m}(b_i / a_{ij}), j = \overline{1,n}, \quad (5)$$

and choosing the one x_s for which the maximum modulus of the product is:

$$|A x_s| = \max_{j=1,n} |c_j x_j|. \quad (6)$$

After that, the standard simplex procedure of enumeration of the system matrix $A_{m\times n}$, vectors B_n and L_n for the general element a_{rs} is performed.

If the task of operations research is formalized in the form of a suitability criterion:

$$\forall X = \|x_{ij}\|_{m\times n}, X \subset \{X\}_M;$$

$$\sum_{j=1}^{n} x_{ij} \le b_i,\ i = \overline{1,m};\ \sum_{i=1}^{m} b_i = B;$$

$$\sum_{i=1}^{m} x_{ij} \le a_j,\ j = \overline{1,n};\ \sum_{j=1}^{n} a_j = A;$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij} \ge \max(A, B), \quad (7)$$

and formalized in the form of an optimality criterion:

$$\exists X^o = \|x_{ij}^o\|_{m\times n},\ X^o \subset \{X\}_M:$$

$$L(X^o) = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} x_{ij}^o = \underset{\{X\}}{extr}\, L(X), \quad (8)$$

then it is a linear programming problem with a matrix argument.

The principle of «dynamic efficiency» to improve the current solution of this problem at each iteration requires the calculation of matrix elements of possible variable increment values:

$$\|\Delta x_{ij}\| = \|(b_i - a_j)\|_{m\times n}, \quad (9)$$

and choosing one of them Δx_{rs} that has the maximum dynamic efficiency:

$$e_{rs} = \max \|e_{ij} = (\Delta x_{ij} / c_{ij})\|_{m\times n}. \quad (10)$$

After this, the component of the current solution x_{rs} is changed to a discrete value, the current values of the constraints b_r and a_s are adjusted. Since a typical «transportation» problem has this formal formulation, the objective function, which has the meaning of «costs», will be minimized at each iteration.

The algorithm of the procedure for solving the integer problem of managing forces and devices of communication using the DE method is as following:

Step 1. Initial assignments taking into account the type of uncertainty about the state of the operational situation:

$$ws := 0;\ ns := 0;\ \|x_{ij} := 0\|_{m\times n}, \|d_{ij} := 0\|_{m\times n};\ k := 1, \quad (11)$$

enter the values of restrictions – permissible labor costs ds^{perm} for the «direct» task and the desired effect vs^{des} for the «inverse» task, enter the values:

$$(a_j), j = \overline{1,n};\ \|\gamma_{ij}\|_{m\times n}. \quad (12)$$

Calculation of the arrays of the «first» criteria according to the formula $\|\delta_{ij}^{(k)}\|_{m\times n}$.

Step 2. Calculation of the DE matrix according to the formula:

$$\|e_{ij} = (\delta_{ij} / d_{ij})\|_{m\times n}.$$

Step 3. Finding the maximum DE on the array:

$$e_{rs} = \max_{ij}(\delta_{ij} / d_{ij}). \quad (13)$$

Step 4. Assignment:

$$vs := vs + \delta_{rs};\ x_{rs} := x_{rs} + 1;\ ds := ds + d_{rs}. \quad (14)$$

Step 5. Checking the condition of the end of the distribution procedure:

– for the direct task of checking the fulfillment of conditions:

$$(ds = ds^{stop}); \quad (15)$$

– for the inverse problem, checking the fulfillment of the conditions:

$$(vs \ge vs^{des}). \quad (16)$$

If «yes», then go to Step 7.

Step 6. Assignment:

$$k := k + 1;\ \delta_{is} := \delta_{is} \times \exp(-\gamma_{rs});$$

$$e_{is} := (\delta_{is} / d_{is}), i = \overline{1,m}, \quad (17)$$

go to Step 3.

Step 7. Solution of the problem (systemic effect, cost of application, optimal plan of distribution of forces and devices of communication by objects):

$$vs; ds;\ \|x_{ij}\|_{m\times n}; \quad (18)$$

minimum composition of communication devices by type:

$$b_i := \underset{j=1,n}{sum}(x_{ij}),\ i = \overline{1,m}, \quad (19)$$

where *sum* is the sum accumulation operation.

The effectiveness of the plan for managing forces and devices of communication is calculated:

$$ef := (ws / ds). \quad (20)$$

This algorithm allows solving both direct and inverse integer problems of optimal control of forces and devices of communication by objects of application for a family of exponential functions of the system effect.

For a vector argument-solution (for the problems of optimal distribution of homogeneous devices on heterogeneous objects), when all matrices are transformed into a ribbon (the only variety of devices), the formal DE method is obviously completely invariant and correct.

In cases, where the partial «effect-cost» functions in the separable function of the system effect are purely nonlinear (not convex), to solve the problems of maximizing the effectiveness of combat systems, the method of dynamic programming (DP) adapted to the conditions of these problems should be used (discreteness of the argument and not the convexity of «enveloping» partial functions).

3.2. Results of the analysis and discussion of the results. In the course of the research, the authors developed a method of managing forces and devices of communication using methods of resource optimization.

The proposed method allows:
– to take into account the type of uncertainty regarding the operational situation in the operational space;
– to take into account the number of members of the group (consumers of communication services) of groups of troops (forces) in operations;
– to take into account the duration of the operation (fighting) while planning measures for the distribution and use of forces and devices of communication;
– to calculate the labor costs necessary to meet the needs of communication services of groups of troops (forces).

The advantages of this research include:
– taking into account the type of uncertainty about the state of the operational situation;
– carrying out a rational distribution of forces and devices of communication among users of communication services;
– simultaneous use of direct and inverse tasks on the distribution of forces and devices of communication among users of communication services. Both problems belong to the class of non-linear programming problems due to the non-linearity of the «duration-cost» function of tasks, paths and the process as a whole. The «inverse» problem of optimal allocation is the «basic» one, since a constraint and an acceptable duration of the operation are always set from above.

The shortcomings of the research include:
– the need to know the type of uncertainty about the operational situation;
– the availability of time to carry out calculations on the distribution of forces and devices of communication of troop groupings (forces) in operations.

It is advisable to implement the specified method:
– in planning documents during planning of the deployment and operation of forces and devices of communication;
– in the software, during operational management of the communication system of troop groups.

The direction of further research should be considered the further improvement of the specified method for an objective and complete analysis of the initial situation.

4. Conclusions

1. The research developed a method for managing forces and devices of communication with the use of resource optimization methods.

2. The novelty of the proposed method consists in:
– taking into account the type of uncertainty regarding the operational situation in the operational space;
– taking into account the number of members of the group (consumers of communication services) of groups of troops (forces) in operations;
– taking into account the duration of the operation (fighting) while planning measures for the distribution and use of forces and devices of communication;
– calculation of labor costs necessary to meet the needs of communication services of groups of troops (forces).

3. The specified method is proposed to be implemented:
– in planning documents during the planning of the deployment and operation of forces and devices of communication;
– in software, during operational management of the communication system of troop groups.

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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Data availability

The manuscript has no associated data.

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