Structuring management tasks in the telecommunication network management system

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Abstract
One of the possible approaches to the distribution of tasks between the management levels of the telecommunication network management system has been proposed. The issues of analysis of management tasks on the basis of ordering information flows and management goals are considered. It is shown that the construction of organizational structures of telecommunication network management systems should be based on a general methodological basis, representing management activities that take place in time and space. The procedure for detecting strongly related tasks, which corresponds to the task of constructing rational spheres of activity. Algorithms for vertical and horizontal structuring of network management tasks are proposed on the basis of analysis of a set of features that describe the features of the initial data and interaction of officials of the network management body. This makes it possible to solve the issue of the distribution of tasks in the management system of the telecommunication network, taking into account their interconnections.

Keywords
Telecommunication network management system, management tasks, task structuring, vertical (hierarchical) structuring, horizontal (group) structuring, organizational structure.

1. Introduction

When creating a telecommunication network management system (TNMS), the question arises of choosing a rational version of its structure. Its solution is based on the use of the principles of structuring and consistency of tasks and the structure of the management system.

Problem analysis is carried out in two main ways. Initially, the information flows of the management system are streamlined on the basis of rational aggregation of management procedures with their simultaneous inclusion in the list of works performed by individual departments or officials of the management system. Then management processes are formed based on the construction of the structure of the goals of the management body of the system. The structure of goals is directly and directly related to the operational aspects of management and has the form of a tree.

Structuring operational tasks creates the best conditions for achieving the goals of system management. It is carried out on the basis of minimizing the amount of duplicate information received for processing by each official or individual structural unit.

The issues of mutual coordination of the tasks solved by the management system and its organizational structure have been considered in many studies. Thus, in the works [1, 2] it is shown that if there is a management function, then there must be a corresponding unit that

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performs it. In most cases, the functions of management systems are defined through the organizational structure, and the organizational structure is defined through functions.

The paper [3] argues that management processes are "stratified" by time levels and concentrated "horizontally" (by time intervals), and not "vertically" (by functions). Therefore, the time level can be a sign of specialization of the operational unit of the governing body. In [4, 5] it is shown that when determining the lower level of aggregation of management tasks solved in organizational structures, it is necessary to proceed from a common goal: the tasks that are constituent parts of ensuring the implementation of the general goal should become the basis for the distribution of the organizational structure's activities between its individual structural units. Consequently, a necessary property of these problems is the relative closure of their connections within a set of problems, provided that their external connections are of much less importance. On the other hand, the complexity of solving these tasks should correspond to the average capabilities of specialists of certain professional and qualification groups – officials of the TNMS management body (MB TNMS). And in the paper [6] it is shown that in management systems the allocation of possible signs of specialization of units or individual officials should be based on a general methodological basis, representing purposeful managerial activity that takes place in time and space. Based on this, the analysis of interrelations of tasks should be carried out on the basis of the totality and mutual influence of functional, temporal and spatial features, taking into account the features of the tasks solved in the MB TNMS.

Currently, there is no comprehensive approach to the mutual coordination of tasks solved by the management system and its organizational structure. The absence of such mechanisms is explained, firstly, by the lack of empirical experience in classifying various kinds of operational tasks and their distribution according to the levels of complexity of the decisions made; secondly, insufficient development of approaches to the rational distribution of decision-making efforts by management bodies; thirdly, the emerging complexity of the synthesis of the hierarchy of management tasks and the micro-level structure of management bodies due to the lack of an unambiguous correspondence between the hierarchies of goals of tasks and the organizational structure [5, 6, 7]. In addition, as a rule, the hierarchy of tasks is more complex than the hierarchy of management bodies. Moreover, the hierarchy of tasks (goals) of the management body can be built both from the bottom up and from the top down by specifying the tasks of a higher level.

The article considers one of the possible approaches to solving the issues of distribution of tasks in the TNMS management system, taking into account the links between them.

2. Structuring of management tasks

Based on the general methodology of designing organizational structures of management systems, the structuring of tasks should meet two criteria: 1) the set of tasks should reflect the nature of their representation in the set of cause-and-effect relationships and correspond to the form of the hierarchical organization of the management system; 2) tasks should not violate the integrity of its organizational structure and should provide the necessary degree of purposefulness of its functioning.

According to the first criterion, structuring procedures should ensure their decomposition in such a way that they would be presented in the form of a hierarchical multi-level structure. Reflecting the nature of the top-down relationships between groups of tasks, such a structure can be considered as a hierarchical structure of subdivisions of different levels of the hierarchy [8].

With regard to the second criterion, it can be noted that within the framework of structuring tasks, tasks are grouped at one horizontal level between two or more subjects. The groupings of tasks obtained in this way will determine the potential areas of activity of the MB units that are at the same level of the hierarchy. Figure 1 shows a variant of the decomposition of tasks X between the levels of the hierarchy of the control system.

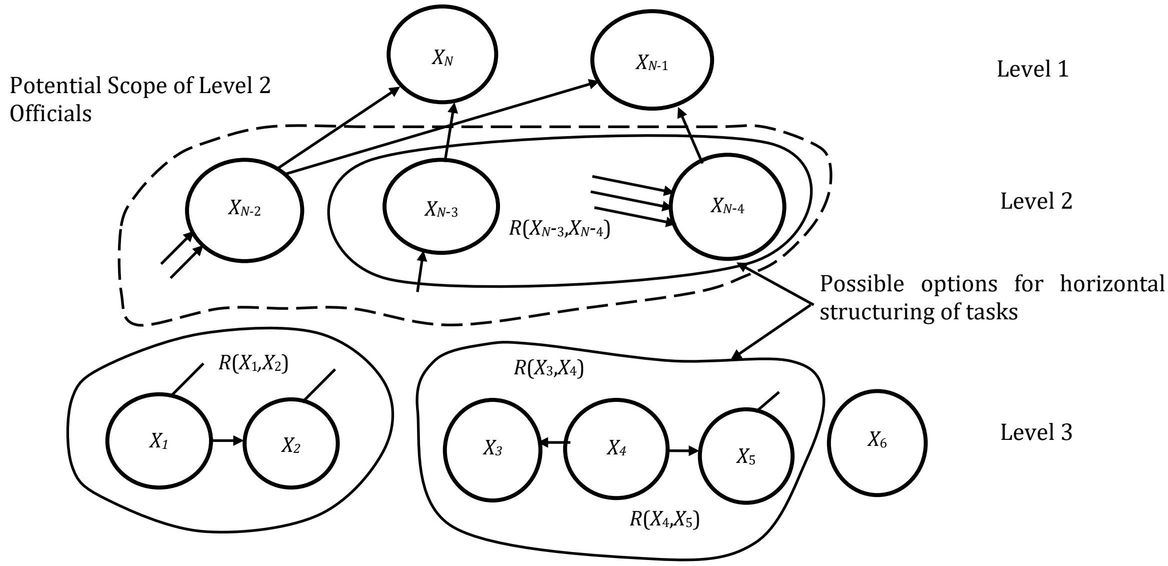


Figure 1: Example of vertical and horizontal structuring of tasks

In this figure, the 1st level is the highest, the 2nd level is the middle level of management, and the 3rd level of management is the lower level of management. Structural functions $R(X_1, X_2)$, $R(X_3, X_4)$, $R(X_4, X_5)$ determine the degree of mutual proximity of tasks X_1 and X_2, X_3 and X_4, X_4 and X_5, at the lower level of control, and structural function $R(X_{N-3}, X_{N-4})$, which determines the degree of mutual proximity of tasks X_{N-3} and X_{N-4} in the middle management. Tasks X_6, X_{N-2}, X_{N-1}, X_N do not have a degree of mutual proximity to other tasks at their levels of control, so they do not have a structural function. The dotted line shows the scope of activity of level 2 officials, and the solid line shows the options for grouping close tasks for the subsystem (subgroup, subdivision).

The presence of intersecting connections between tasks (for example, in Fig. 1 these are the links between X_{N-2} and X_N, as well as between X_{N-3} and X_N, X_{N-2} and X_{N-1}), which form the basis of the elements of the MB activity, often leads to the appearance of cycles, which excludes their vertical structuring. The presence of cycles indicates the existence of a set of strongly connected tasks that are resolved in the course of cyclical exchange of information (in the process of internal dialogue). Such tasks cannot be separated within a given level of decomposition of the group's activities. They are considered as one task (as one complex element of activity), and if it is necessary to study a more subtle structure of activity, their analysis is carried out separately.

Identification of strongly related tasks can be done by the following procedure:

On the set of problems X, a certain structural function $R(x_i, x_j)$ is calculated, which determines the degree of their mutual proximity. The function is defined in the range from 0 to 1.

The step of varying the parameters of structuring tasks ΔR is selected. It determines the discreteness of the choice of structural parameters of tasks, as well as options for organizing the organizational structure.

The concept of "structuring step" is introduced. Z $(Z = 1, 2, 3, \dots)$.

On the set of values of the function $R(x_i, x_j)$ $(i, j = \overline{1, L}; L = |X|;)$ – the number of types of control problems), a discrete function is formed:$R_Z(x_i, x_j)$

$$R_Z(x_i, x_j) = \begin{cases} R(x_i, x_j), \text{ where } R(x_i, x_j) \geq Z\Delta R \\ 0, \text{ otherwise,} \end{cases}$$

and a graph $G_Z(X, Y_Z)$ of interrelations of the vertex of the graph is constructed (corrected), X – and the arcs of the graph Y_Z determine the directional connections of the problems equal to:

$$Y_Z(x_i, x_j) = \begin{cases} Y(x_i, x_j), \text{ where } R(x_i, x_j) \geq 1 - Z\Delta R; \\ 0, \text{ - otherwise.} \end{cases}.$$

When the parameter Z is changed, the structure of the graph $G_Z(X, Y_Z)$ of mutual relations of tasks will also change at the Zth step of structuring. By changing Z from Z_{min} to Z_{max} it is possible to generate all the options for structuring them that are acceptable for a given set of tasks on the basis of such a procedure.

Thus, on the set of vectors ordered in this way, for each variant of the definition of the discrete coupling function, the problems $R_Z(x_i, x_j)$ of vertical and horizontal structuring are sequentially weighed. Algorithms of vertical and then horizontal structuring are applied to the resulting graph $G_Z(X, Y_Z)$.

3. Algorithm of vertical structuring of management tasks

As a result of decomposition and elimination of intersecting relationships between problems, the structure of control problems will be represented by a directed graph, in which strongly connected subgraphs are represented by separate vertices. Therefore, an important property of the graph $G_Z(X, Y_Z)$ is its acyclicity, which actually indicates the absence of contradictions between control problems. It is also true for the graph $G_Z(X, Y_Z)$:

$$Y_Z(x_i, x_j) = \begin{cases} 1, \text{ where } R_Z(x_i, x_j) \geq (1 - Z\Delta R); \\ 0, \text{ where } R_Z(x_i, x_j) < (1 - Z\Delta R). \end{cases}$$

In the graph obtained in this way $G_Z(X, Y_Z)$, the internal hierarchy of tasks is presented implicitly. The complexity of the hierarchical representation of such a graph lies in the fact that the presence of cross-connections between tasks leads to the fact that its structure can be represented in the form of a graph only with a predominantly hierarchical order, and not as "pure trees".

The paper [6] proposes a heuristic method for transforming a graph $G_Z(X, Y_Z)$ into its corresponding tree. Its essence is as follows. It is necessary to select in the graph the vertex that corresponds to the global goal (for a given task or group of tasks) and place it at the first (upper) level of the hierarchy; then select the sub-goals and place them on the next second level of the hierarchy; then, for each sub-goal of the second level, select those of them, which is a prerequisite for achieving the sub-goals of the second level and placing them on the third level, and so on, until those sub-goals that are kind of primary remain at the lower levels of the hierarchy. The resulting tree is redundant.

The disadvantages of this graph transformation method include the complexity of its automated implementation. In addition, this method gives an excessive structure of the hierarchical distribution of tasks, in this respect it is not optimal, does not take into account the multidimensionality of the target guidelines of the organizational structure and the functional differences in the tasks of the activity of a group of operators in the process of system management. With this in mind, a different approach to the analysis of the hierarchy of tasks solved by the organizational structure in management systems is proposed.

Namely, the tasks of the management system structure, which are directly related to the operational aspects of management, express the goals of management at different levels of the hierarchy of its organization. The need for their successful solution in a dynamically changing external environment is different. The level of this need actually reflects the degree of influence of a particular sub-goal on the achievement of the global goal of the unit. Thus, in general terms, each task should be associated with a certain quantitative value that determines the usefulness of its error-free and timely solution in the process of activity. The inverse value of this parameter determines the disorder in achieving the necessary criterion for the activity of an official (or a group of persons) at a given level of the hierarchy of the management system structure $x_i v_i$.

Defining the heterogeneity in the achievement of the goal, which is expressed by the results of solving management problems, as a measure of divergence of any selected parameter v_i in relation to the standard of order v_{ie}, it should be noted that the goal of the activity of any official of the management system, if it is not specifically motivated, is to achieve an equilibrium state of information flows coming from the outside (i.e., operational tasks) and the flow of solved (in the sense of accuracy and timeliness) tasks. Hence, it can be assumed that in the absence of motivational differentiation of tasks, their weight, felt subjectively by any official of the management group, will be determined by the necessary intensity of their solution. In this case, the disorder of the official's activity in achieving his partial goal can be assessed by the extent of the tasks not performed by him, due to his functional duties.

Let the structure of the problems be represented by a graph $G_Z(X, Y_Z)$ and a discrete weight function $v_i(x_i)$ is given on the set X, which characterizes, in the general case, the complexity and importance of the timely and error-free solution of i th control problem. Then the problem of determining the rational hierarchy of the system of control problems can be represented as the problem of determining the ordinal function of an acyclic graph.

To do this, we define the subsets $X_1, X_2, \dots, X_s$:

$$\begin{aligned} X_1 &= \{x_i | x_i \in X,\ z^{-1}x_i = \emptyset\}; \\ X_2 &= \{x_i | x_i \in X - X_1,\ z^{-1}x_i \in X_1\}; \\ X_3 &= \{x_i | x_i \in X - (X_1 \cup X_2),\ z^{-1}x_i \in X_1 \cup X_2\}; \\ X_s &= \left\{x_i | x_i \in X - \textstyle\bigcup_{k=0}^{s-1} X_k,\ z^{-1}x_i \in \bigcup_{k=0}^{s-1} X_k\right\}, \end{aligned} \tag{1}$$

where s is the smallest number of levels in the hierarchy that $z^{-1}x_s = \emptyset$;

$z^{-1}x_i$ means crossing out the vertices $x_i \in X_k$ of the graph $G_Z(X, Y_Z)$.

The subsets ($X_k k = \overline{1, s}$) form a partition of the graph $G_Z(X, Y_Z)$, which is ordered by the relation: $X_k - X_{k'} <=> k < k'$.

The set of vertices of a graph $G_Z(X, Y_Z)$ is divided into non-intersecting subsets, which are ordered in such a way that if the vertex of the graph belongs to a subset with number k, then the vertex following it is included in the subset with a number greater than k.

The subsets X_k form hierarchical levels of tasks that are solved in the organizational structure. Each k th task of the th level ($k = \overline{1, s}$) is associated with a corresponding tree of its subtasks, the results of which are considered as initial data. Obviously, the higher the level of the hierarchy of tasks of the subset X_k, the higher the level of training of officials who solve them. Therefore, each subset of tasks X is associated with certain requirements for the qualification characteristics of officials, and, consequently, the cost characteristics of their professional selection, training and maintenance.

Thus, the sequence of determining the ordinal function of a graph is as follows:

1. The adjacency matrix $A = \|a_{ij}\|$ of the graph $G_Z(X, Y_Z)$,

$$a_{ij} = \begin{cases} 1, \text{ when arc goes from } i\text{-th vertex to } j\text{-th,} \\ 0, \text{ - otherwise.} \end{cases}$$

2. The first line of the matrix of weights is calculated v^1

$$v^1 = \{v_j^1 : j = \overline{1, L}\},\ v_j^1 = \textstyle\sum_{i=1}^{L} (v_i)^{a_{ij}},\ i = \overline{1, L}, \tag{2}$$

where $v_j^1 -$ is the weight of the j-task, taking into account the sum of the weights of the "subordinate" tasks.

3. The set of tasks of the 1st level of the hierarchy is determined

$$X_i = \{x_j | v_j^1 \le v_э\},\ x_j \in X, \tag{3}$$

That is, the 1st level of the hierarchy includes tasks x_j whose weight is less than the established threshold v_e.

4. Vertices are crossed $x_j \in X_i$ out from the graph $G_Z(X, Y_Z)$ and the adjacency matrix is corrected (columns and rows corresponding to the vertex x_j are crossed out).

5. Paragraphs 2–4 are performed for the following levels of the hierarchy $k = 2,\dots,s$ $G_Z(X, Y_Z)$, taking into account the correction of the graph and adjacency matrix:

$$v^k = \{v_j^k\},\ X_k = \{x_j | v_j^k \le v_e^k\},\ x_j \in X - \cup_k X_k\ .$$

6. The breakdown of the original set X ends if all its elements are distributed at the appropriate levels of the hierarchy, i.e.

$$\boldsymbol{v^k = \emptyset}\ .$$

The belonging of a task x_j to the hierarchical level is determined either by its own weight and the corresponding requirements for the qualifications of the official, or by the total weight of "subordinate" tasks solved at the lower levels of the hierarchy of the organizational structure.

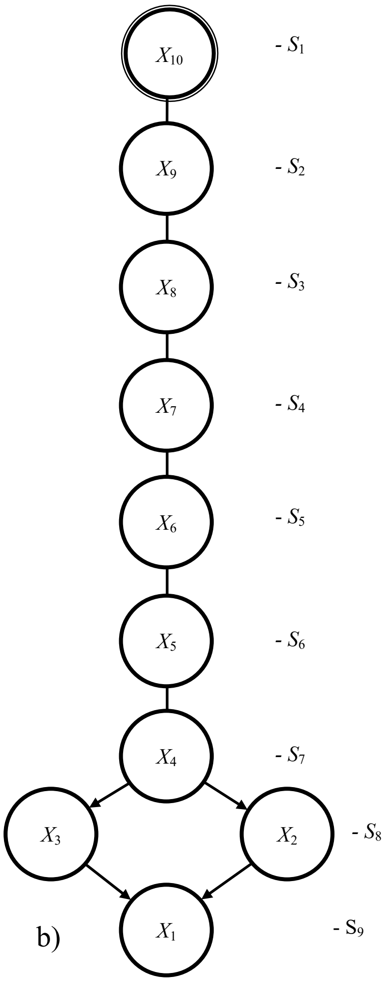
Let's consider an example of vertical structuring of tasks. According to the above sequence of determining the ordinal function of a graph at the first step of structuring, we determine the matrix of adjacency of problems and connections when an arc goes from the i-th vertex to the j-th vertex (Fig. 2).

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
x_1											1
x_2	1										1
x_3											1
x_4	1	1	1								1
x_5	1	1	1	1							1
x_6	1	1	1		1						1
x_7			1	1	1	1					1
x_8	1	1					1				1
x_9	1	1	1	1	1	1	1	1			1
x_{10}			1	1	1	1	1	1	1		1
x_{11}											

Figure 2: Boolean matrix of mutual relations of problems (*Z=0*)

L_0	6	5	6	4	4	3	3	2	1	0	10
L_1	6	5	5	3	3	2	2	1	0	x	9
L_2	5	4	4	2	2	1	1	0	x	8	8
L_3	4	3	4	2	2	1	0	x	x	x	7
L_4	4	3	3	1	1	0	x	x	x	x	6
L_5	3	2	2	1	0	x	x	x	x	x	5
L_6	2	1	1	0	x	x	x	x	x	x	4
L_7	1	0	0	x	x	x	x	x	x	x	3
L_8	0	x	x	x	x	x	x	x	x	x	1
L_9	x	x	x	x	x	x	x	x	x	x	0

a)



b)

Figure 3: Sequence of calculation of the matrix of weights (a) and vertical structure of interrelations of problems (b)

Next, we carry out the calculation according to (2), the above sequence of determining the ordinal function of the graph, the first line of the matrix of weights v^1 (Fig. 3a). Determine according to (3) the set of tasks of the 1st level of the hierarchy. From the graph, $G_Z(X, Y_Z)$ which is built as a result of vertical structuring of problems, we cross out the vertices $x_j \in X_i$ and adjust the adjacency matrix (columns and rows corresponding to the vertex x_j are crossed out). Steps 2–4 are performed for the next levels of the hierarchy $k = 2,\dots,s$, taking into account the correction of the graph $G_Z(X, Y_Z)$ and matrix adjacency. The breakdown of the original set X ends if all its elements are distributed at the appropriate levels of the hierarchy. As a result, we obtain a vertical structure of interrelations of tasks (Fig. 3b).

In the presence of a significant number of tasks, cycles may appear in their execution. The presence of cycles indicates a violation of the correctness of the choice of elements of activity, and the presence of strongly related tasks solved on the basis of mutual exchange of information. Strongly related tasks are taken into account separately – they are considered as one task and special algorithms are used to identify them [6-9].

4. Algorithm of horizontal structuring of management tasks

We will assume that as a result of the vertical structuring of tasks, the levels of the hierarchy $k = 1,\dots,s$ are allocated. Consider a finite set of problems $X_k \in X$. On this set, a real function $(R_Z(x_i,x_j)x_i,x_j \in X_k)$ is given with the properties:

$$R_Z(x_i,x_j) \geq 0,\ R_Z(x_i,x_j) = R_Z(x_j,x_i),\ \forall x_i,x_j \in X\ .$$

Horizontal structuring of management tasks involves the division of the set (X_k) of tasks of each k level of the hierarchy into a given number of groups of tasks with maximum internal connections. The groups of tasks found in this way will determine the rational spheres of activity of individual officials at each k level of the hierarchy of the organizational structure of the group.

The considered problem of horizontal structuring of elements of activity belongs to the class of tasks of automatic classification. Automatic classification algorithms can be represented by three large groups [6, 7, 10, 15]: heuristic algorithms; variational algorithms; algorithms related to the problem of mixture separation (statistical algorithms). Selection This or that algorithm for structuring tasks is carried out on the basis of an analysis of a set of features that describe the features of the initial data and the features necessary for the organization of interaction of officials, which characterize the properties of the final breakdown of tasks [6, 10].

According to a set of features that characterize the features of the initial data (the number of tasks to be classified; the dimension of the set of problem relations; the type of restrictions on the number of problems in the class, etc.). Taking this into account, the choice of such an algorithm can effectively be made, for example, by one of the methods [16, 17], which are modifications of the method of hierarchy analysis in cases of single or group selection. The result of the analysis shows that the classification algorithm described in the works [6, 10] takes into account these features to the greatest extent [6, 10].

For its formal description, consider the following definitions.

Definition 1.

A set B $(B = X_k)$ containing more than one element is called a group if for any elements x_i and x_j that set there exists a sequence $c_1, c_2, \dots, c_{L_k}$, where $c_i \in B$, $c_1 = x_i$, $c_{L_k} = x_j$ $(L_k = |X|)$ such that

$$\min_{c_i \in B} R(c_i, c_{i+1}) > \max_{\substack{d \in B \\ l \in X_k \setminus B}} (d, l) \tag{4}$$

Definition 2. Let $a, b \in X_k$. Let's b call it a neighbor if

$$\max_{c_i \in X_k \setminus a} R(a, c_i) > R(a, b)\ \text{, ie.} a \to b \tag{5}$$

Definition 2 implies an obvious property of a group: any element is included in a group along with its neighbors.

Definition 3. A set D $(D = \mathrm{X_K})$ is called a pseudogroup if any element of that set is included in it along with all its neighbors.

Let us denote F_k by the set of all possible partitions X_k into pairwise non-intersecting pseudogroups. On a set F_k, partial ordering can naturally be introduced. Let F_1, $F_2 \in F_k$. According to definition 3, is F_1 preceded by F_2, if any element F_1 can be represented as a union of elements with F_2. In this set of breakdowns, there is a minimum that holds only one element X_k– the plural itself. It is proved [12, 14] that the maximum division of a set F_k is unique, that is, there is a single division of this set into pairwise non-intersecting sets that have the following property: if a and b belong to one of these subsets, then they can be connected by a chain of the form $a \to c_1 \to c_2 \to \ldots \to c_m \to b$, and if not, then such a sequence cannot be constructed. This breakdown is a breakdown into pseudogroups.

The maximum element of the set F_k is called the base partition. Let us denote the set of elements of the basic breakdown by X_{k1} and define the function $R_1(D, \mathrm{C})$ on it as follows:

$$R_1(\mathrm{D}, \mathrm{C}) = \begin{cases} \max\limits_{a \in \mathrm{D},\, b \in C} R(a, b), \text{ where } \mathrm{D} \neq \mathrm{C}; \\ \min\limits_{a \in \mathrm{D}} \max\limits_{b \in D \backslash a} R(a, b), \text{ where } \mathrm{D} = \mathrm{C}. \end{cases}$$

Definition 4.

Let $D \in X_{k1}$. We will call an element C a neighbor of D if

$$\max_{\mathrm{E} \in X_{k1}} R(D, \mathrm{E}) = R(D, \mathrm{C}) \text{ , ie.} D \to \mathrm{C} \tag{6}$$

Next, you can enter the definition of the pseudogroup and show that the definitions formulated earlier will be valid.

Let us denote Q_k in terms of the set X_k all possible divisions of the set into pairwise non-intersecting groups. It is true that Q_k in order for a set X_k to be divided into groups, it must correspond to the division of the set X_{k1} into pseudogroups. The proof of the statement is given in [13, 15].

It follows from the statement that any division of a set X_k into groups can be represented as a union of elements with F_1 (F_1– the maximum division of the set X_{k1} into pseudogroups). If we denote $X_{k2} = F_2$ and introduce on the set X_{k2} a measure of proximity $R_2(L, M) = max\, R_1\,(D, \mathrm{C})$, then with respect to the set X_{k2} all the statements that for X_{k1}. Similar conclusions can be drawn with respect to any intermediate set X_{kZ^*}.

This process ends when each of the following two solutions is present:

- at some step Z^*, a set with a single element X_{kZ^*} containing all the elements of the set X_k is obtained, i.e. the breakdown of tasks of a given level of the hierarchy is impossible by formal methods and it is necessary either to use heuristic procedures or to change the structure of the initial data:

$$X_{kZ^*} = X_k; \tag{7}$$

- with some $Z^* > 2$ $X_{kZ^*} = X_{kZ^*-1}$ i X_{kZ^*} and does not consist of any element. In this case, the elements of the set X_{kZ^*-1} are pseudogroups, and the set X_{kZ^*-1} corresponds to the division of the original set X_k into groups:

$$X_{kZ^*} = X_{kZ^*-1}. \tag{8}$$

Thus, the algorithm for horizontal grouping of management tasks can be represented as follows:

1. The original set X_k and the function $R_Z(x_i, x_j)$ of the interconnection of the problems$x_i, x_j \in X_k$ are written. We get the graph $G_Z(X, Y_Z)$.

2. According to expression (4), for each element of the set X_k, neighbor elements are determined and pseudogroups of the first ($Z^* = 1$) of the basic breakdown $D_l \in X_{k1}$ are written.

3. Condition (7) is checked. If the elements of the set X_k make up one pseudogroup, then partitioning by formal methods is not possible.

4. On the set X_{k1}, according to expression (5), a function of the degree of mutual proximity between pseudogroups, is formed $R(D_i, D_j) D_i, D_j \in X_{k1}$.

5. According to expressions (6) and (7), for each element D_l of the set X_{k1}, neighbor elements are determined and pseudogroups of the second ($Z^* = 2$) of the basic division are written.

6. Condition (8) is checked. If it is not fulfilled, then paragraphs 4 - 8 are repeated for the third ($Z^* = 3$) and so on breakdowns.

7. If condition (8) is satisfied, then the set X_{kZ^*} corresponds to the maximum breakdown and it is necessary to proceed to the horizontal grouping of the remaining tasks of the hierarchy levels X_k, $k = \overline{1, s}$. With each step Z^*, the breakdown of the initial set of tasks at a given level of the

organizational structure hierarchy is associated with checking the feasibility of including a group of officials in the organizational structure $m_{kZ^*} = |X_{kZ^*}|$ at this level.

Let's look at an example of horizontal structuring of tasks.

Let $X = (x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11})$ be the set of problems that are solved in the network management body. Figure 4 shows a graph $G_Z(X, Y_Z)$ of mutual relations of problems, and in Figure 5 – matrix of measures of their proximity.

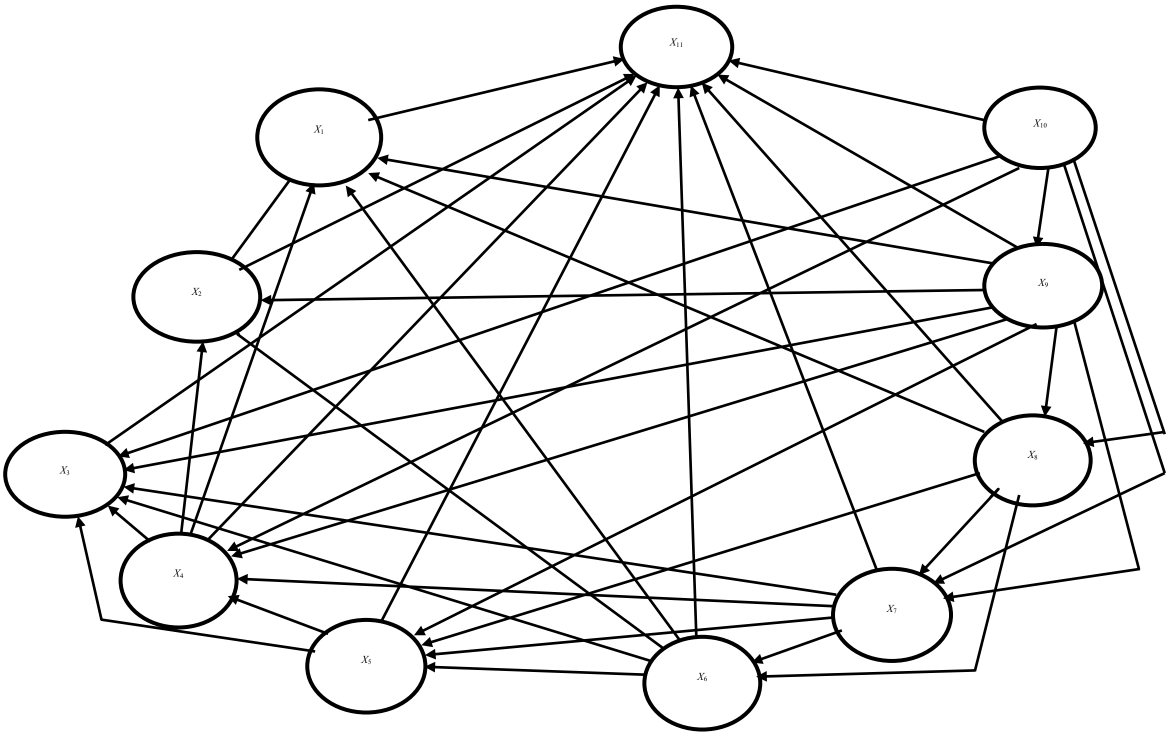


Figure 4: Graph of mutual relations of problems

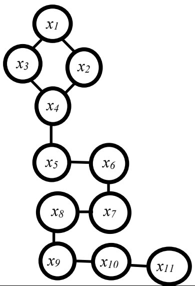
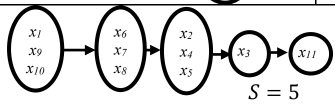
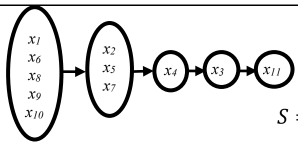
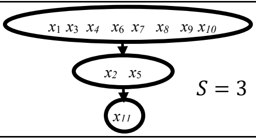
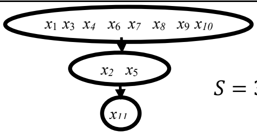
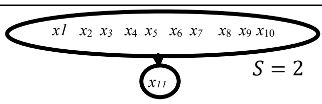
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
x_1	1	1/7		1/14	1/13	1/13		1/8	1/10		1
x_2		1		1/14	1/6	1/5		4/5	1/4		1
x_3			1	1/2	1/14	1/16	1/3		1/13	1/2	1
x_4				1	1/13		1/2		1/13	1/3	1
x_5					1	4/5	1/13	1/7	1/2		1
x_6						1	1/14		1/3		1
x_7							1	1/9	1/11	1/2	1
x_8								1	1/4	1/11	1
x_9									1	1/10	1
x_{10}										1	1
x_{11}											1

Figure 5: Matrix $R(x_i, x_j)$ of measures of proximity of tasks

In accordance with the algorithm of horizontal grouping of management tasks, we will perform the procedure of horizontal structuring of tasks. To do this, we will use the algorithm for calculating the ordinal function of the graph. Let $R = 0.2$. By sequentially changing the structuring step $Z = 0 \ldots 5$, the following structures of graphs of mutual relations of problems are obtained (Table 1).

The table shows the six steps of structuring tasks ($Z = 0 \ldots 5$). At each of these steps, according to the above algorithms, the options for vertical and horizontal structuring are shown. The range of changes in the values of the hierarchy obtained on this structure $S = 2 \div 10$.

Table 1.
Structure of graphs of mutual relations of problems

Step Number	Structures Generated by Vertical Structuring of Tasks		Options for horizontal structuring of tasks
$Z = 0$		$S = 10$ $S = 9$ $S = 8$ $S = 7$ $S = 6$ $S = 5$ $S = 4$ $S = 3$ $S = 2$ $S = 1$	$m_1 = m_2 = m_3 = m_4 = m_5 = m_6 = m_7 = m_9 = 1;\ m_8 = 1.2$
$Z = 1$	 $S = 5$		$m_1 = \{1,3\}$; ;$D_1^1 = \{x_1, x_9, x_{10}\}$ $m_2 = \{1,3\}$; ;$D_1^2 = \{x_6, x_7, x_8\}$ $m_3 = \{1,2,3\}$; ;$D_1^3 = \{x_2, x_4, x_5\}$ $D_2^3 = \{\{x_2, x_5\}, x_4\}$
$Z = 2$	 $S = 5$		$m_1 = \{5,3\}$; ;$D_1^1 = \{x_1, x_6, x_8, x_9, x_{10}\}$;$D_2^1 = \{\{x_1, x_8, x_9\}, x_6, x_{10}\}$ $m_2 = \{3,2\}$; ;$D_1^2 = \{x_2, x_5, x_7\}$ $D_2^2 = \{\{x_2, x_5\}, x_7\}$
$Z = 3$	 $S = 3$		$m_1 = \{8,3,2\}$; $D_1^1 = \{x_1, x_3, x_4, x_6, x_7, x_8, x_9, x_{10}\}$; $D_3^1 = \{\{x_1, x_8\}, \{x_9, x_4, x_7, x_{10}\}, \{x_9, x_6\}\}$; $m_2 = \{2,1\}$; $D = \{\{x_1, x_6, x_8, x_9\}, \{x_3, x_4, x_7, x_{10}\}\}$
$Z = 4$	 $S = 3$		$m_1 = \{8,3,2\}$; $D_1^1 = \{x_1, x_3, x_4, x_6, x_7, x_8, x_9, x_{10}\}$; $D_3^1 = \{\{x_1, x_8\}, \{x_9, x_4, x_7, x_{10}\}, \{x_9, x_6\}\}$; $m_2 = \{2,1\}$; $D = \{\{x_1, x_6, x_8, x_9\}, \{x_3, x_4, x_7, x_{10}\}\}$
$Z = 5$	 $S = 2$		$m_1 = \{10,3,2\}$; $D_1^1 = \{x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}\}$; $D_2^1 = \{\{x_1, x_2, x_8\}, \{x_{10}, x_3, x_7, x_4\}, \{x_9, x_5, x_6\}\}$; $D_3^1 = \{\{x_1, x_2, x_5, x_6, x_8, x_9\}, \{x_3, x_4, x_7, x_{10}\}\}$

A variant of horizontal structuring of tasks has been obtained. Next, you need to define the neighboring elements of the set and write down the pseudogroups of problems of the first basic breakdownX_k. To do this, we solve the problem of horizontal structuring of the 5th variant of the breakdown, the conditions of which are fulfilled at $Z = 5$. The hierarchy of vertical structuring of the spheres of activity of officials in this variant has two levels $S = 2$.

As can be seen from Table 1, all the tasks that support the group's activities are focused on the first level. The matrix of interrelations of the tasks of the first level is presented in Fig. 6.

Using the algorithm of horizontal structuring of control problems, we obtain the first basic breakdown of the original set N_1:

Areas of activity of Level 1 officials:
a) $x_1^1 = \{x_1, x_2, x_8\}$;
b) $x_2^1 = \{x_{10}, x_3, x_7, x_4\}$;
c) $x_3^1 = \{x_9, x_5, x_6\}$.
$N_{11} = \{x_1^1, x_2^1, x_3^1\}$

In particular, starting with the problem x_1, we successively obtain the set of "neighbor" problems formed by it $\{x_1 \rightarrow x_2 \leftrightarrow x_8\} = D_1$. Continuing the process, we select the sets $D_2 = \{x_{10}, x_3, x_7, x_4\}$ and $D_3 = \{x_9, x_5, x_6\}$. D_1, D_2 and D_3 form pseudo-groups of problems of the first basic breakdown of the first stage. Each pseudo-group characterizes the sphere of activity of one official at the $k = 1$ level of the hierarchy of the organizational structure. Thus, for $Z^* = 1\ \ m_1 = |N_{11}| = 3$.

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
x_1	1	1/7		1/14	1/13	1/13		1/8	1/10	
x_2		1		1/14	1/6	1/5		4/5	1/4	
x_3			1	1/2	1/14	1/16	1/3		1/13	1/2
x_4				1	1/13		1/2		1/13	1/3
x_5					1	4/5	1/13	1/7	1/2	
x_6						1	1/14		1/3	
x_7							1	1/9	1/11	1/2
x_8								1	1/4	1/11
x_9									1	1/10
x_{10}										1

Figure 6: Matrix of measures of proximity of tasks of the first level of the hierarchy

Pseudogroups D_1, D_2, D_3 are elements of the set N_{11}. A function can also be built on this set $R\left(x_i^1, x_j^1\right)$.

Areas of activity of Level 1 officials:

a) $x_1^2 = \{x_1, x_2, x_5, x_6, x_8, x_9\}$;

b) $x_2^2 = \{x_3, x_4, x_7, x_{10}\}$.

$N_{11} = \{x_1^2, x_2^2\}$

Pseudogroups of the basic division of the set N_1 look like this: $D_1^1 = \{x_1^1, x_3^1\}$, $D_2^1 = x_2^1$. Pseudogroups D_1^1 and D_2^1 will form spheres of activity for two officials of the 1st level of the group hierarchy.

On the set $x_1^2 = D_1^1$, $x_2^2 = D_2^1$, let us construct the function $R_2(x_1^2, x_2^2)$. As a result of the analysis of the obtained set $N_{12} = \{D_1^1, D_2^1\}$, we find the following pseudogroups of the basic division of the third stage: $N_{13} = \{a_1^2, a_2^2\}$, i.e. $N_{13} = N_{12}$. From this it follows that individual problems of a set of problems N_1 will form two groups:

$$D_1^2 = \{x_1, x_2, x_5, x_6, x_8, x_9\}.\ D_2^2 = \{x_3, x_4, x_7, x_{10}\}$$

Similar calculations are performed for all variants of the previous stage of vertical structuring of tasks.

Conclusions

An approach to the distribution of tasks between the levels of management of a telecommunication network is considered. An algorithm for vertical structuring of tasks in TNMS control systems is presented. This algorithm makes it possible to effectively distribute tasks by management levels based on the analysis of information flows and the hierarchy of goals, as well as to synthesize the organizational structure of the TNMS as a whole.

An algorithm for horizontal structuring of tasks is also provided, which allows automating the process of forming various options for the spheres of activity of officials in the organizational structure at each level of the hierarchy. At the same time, the nature of the mutual relations of tasks is taken into account, which reflect the target orientation of the organizational structure. The variants of structuring tasks obtained as a result of generation serve as a further oriented basis for the selection of appropriate structures for the organization of activities of the structural elements of the TNMS and allow to exclude from consideration the variants of organizational structures that do not correspond to the structure of tasks that are solved in the management system.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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