SYNTHESIS OF LOCAL AREA NETWORK STRUCTURE IN UNCERTAIN CONDITIONS OF INITIAL INFORMATION

The problem of taking into account the uncertainty of the initial information is identified in the tasks of the structure synthesis of local area networks. The analysis of the factors generating uncertainty is carried out, the sources of uncertainty are singled out and the approaches to formalization and research of uncertainty are systematized. Probabilistic-statistical, interval, fuzzy and deterministic approaches were reviewed, as well as statistical, subjective, logical interpretations of probability and stochastic description, concept of interval-probabilistic approach, continuously determined and discretely determined models. The formulation of the problem was formed and it was proposed to apply the theory of fuzzy sets to formalize and study an uncertainty in synthesizing the structure of the local computing network, the main elements of which are user points, the centers of processing of the information, switching devices and communication channels. The implementation of information and computing works which sources are subscriber points, is assigned to the centers of information processing. It is assumed the popularity of volumes of information and computing works and geographical coordinates of the location of network elements. A model for a research problem based on a cost criterion has been developed. Cost parameters are divided into well-defined and having an uncertain nature. Fuzzy parameters are proposed to describe the membership functions of the form "approximately equal" or "is approximately in the interval". Restrictions on technical capabilities of information processing centers, switching devices, traffic in communication channels are singled out. The technology of model research based on the idea of solving the problems of linear programming in fuzzy statement is proposed. The technology provides the decision maker with information about the network structure, its cost and the level of ownership of the solution. The results of the work can be used in the development of approaches to solving problems of structural-topological synthesis of local area networks, design, development and implementation of appropriate software solutions.

Keywords: local area network, uncertainty, probabilistic and statistical approaches, interval approach, fuzzy approach, deterministic approaches, structure synthesis, model, fuzzy cost criteria, research technology
**Introduction.** The efficiency of using computing and peripheral equipment is increased due to the implementation of local area networks (LAN) [1].

It is necessary to go through many stages to get benefits from using the LAN: determine the purpose, choose the implementation option, analyze information flows, identify data storage and processing centers, form the structure, configure and test the LAN. One of the key stages is the LAN structure formation. It is important to take into account many different parameters, including those that may have an indefinite nature. Therefore, issues of formalization and uncertainty research are important and relevant.

**Analysis of approaches to the formalization and study of uncertainty.** We can identify factors causing uncertainty [2]: complexity, human and environmental factors. Then the sources of uncertainty can be divided into three groups: the randomness of the processes under consideration, the distortion and inaccessibility of information about possible events and processes, and opposition from other systems.

Systematizing [3–7], we single out approaches to formalization and the study of uncertainty.

Probabilistic-statistical approaches. This class of approaches is based on a statistical, subjective, and logical interpretation of probability with a stochastic description. The statistical interpretation of probability identifies probability with the relative frequency of a mass random event occurrence at sufficiently long tests. In conditions of limited experiment we are limited to selective estimates. The reliability of the results obtained on their basis depends on the existence of qualitative and voluminous statistical information. In a subjective interpretation of the probability, the probability is interpreted as the "degree of confidence" in the value of the uncertainty factor under consideration. The logical interpretation of probability is associated with an attempt to validate hypotheses based on logical considerations. Stochastic description is expedient if uncertainty factors can be attributed to probabilistic character and their probability density can be set.

The interval approach assumes the description of uncertainty factors in the interval form by the range of possible values of variables or dependencies. Accordingly, the length of the range is interpreted as a natural measure of uncertainty. The concept of the interval-probabilistic approach describes the available data by a set of close probability distributions, and weakens the assumption of statistical homogeneity of the observed events in the construction of probability hypotheses.

The fuzzy approach assumes that the elements of human thinking are not numbers, but sets, for which the transition from "belonging" to "non-belonging" is continuous. The main features of the approach are: the use of fuzzy and linguistic variables, the use of simple and complex relationships.

Deterministic approaches to accounting for uncertain factors play a significant role in the practice of creating various systems. Input and output variables are deterministic, internal connections in the system are known. It is assumed that there is a causal relationship between the choice of a certain alternative and the onset of a corresponding outcome. Continuously deterministic and discretely deterministic models can be used to model systems.

**Formulation of the problem.** When building the structure of a LAN, it is important to take into account its constituent elements, the links between them, the presence of information flows, and the impact of external and internal environmental factors. This leads to the fact that the synthesis of the LAN structure can be influenced by uncertainty. Ignoring the accounting for uncertainty may lead to inadequate models and the adoption of unjustified decisions. Probabilistic-statistical, deterministic interval and fuzzy approaches can be used to formalize and assess uncertainties. If there is a lack of information for the application of probabilistic models, difficulties in operation with random variables, the ability to work with interval values within the limits of the fuzzy approach, it is expedient to apply the theory of fuzzy sets.

Thus, the paper proposes to consider the problem of the synthesis of the LAN structure in the conditions of uncertainty of the initial information, the generating factor of which we will consider the external environment. A fuzzy approach is applied to formalize uncertainty.

When building a LAN structure, problem statements based on the following criteria may be relevant depending on the performance indicator: cost, performance, reliability [8, 9]. Since the external environment has the greatest influence on the parameters that are independent of the internal processes of the enterprise, attention is paid to the cost criterion.

Among the variety of topological realizations of LAN [10], the paper considers radial node with an arbitrary number of levels of data switching.

Based on the ideology of the implementation and use of LAN, we will assume that the LAN has the task of serving the set \( I = \{i \in I\} \) subscriber stations (SS). SS are the sources of informational computational works (ICW), the execution of which is entrusted to the set \( J = \{j \in J\} \) of information processing centers (PIC). The transfer of the ICW from the SS to the PIC is performed via communication channels (CC) using the set \( K = \{k \in K\} \) of switching devices (SD). It is assumed that the ICW volumes \( \{h_{jk}\} \), the geographical coordinates of the SS, PIC and SD are known, and the distance vector \( d = \{d_{vw}\} \), where \( v, w \in I \cup J \cup K \), \( v \neq w \) is defined accordingly.

Thus, the aim of the work is to develop a model for the synthesis of the LAN structure based on the cost criterion, taking into account the uncertainty of the initial data. The development of technology for the study of the synthesis model of the LAN structure is also given special attention in the work.

**Model of synthesis of LAN structure.** From the point of view of the presence of the LAN structure of the SS, PIC, SD, each of which can be implemented by one of the valid options \( s \in S_i, q \in Q_j, m \in M_k \), we introduce the vector of Boolean variables \( x = \{x_{ij}\}, y = \{y_{jk}\}, z = \{z_{im}\} \), and the topology and variants of the implementation of the CC with the type \( l \) from the admissible set \( L \) will be described with \( a = \{a_{kl}\}, b = \{b_{kj}\}, y = \{y_{jk}\} \) and \( e = \{e_{km}\} \). Moreover, let \( a_{kl} \) be a Boolean variable, which
determines the variant of connecting the SS \( i \) to the output of the SD \( k \) using CC \( l \), \( β_j^l \) – PIC \( j \) to the output of the SD \( k \) using CC \( l \), \( γ_j^k \) – PIC \( j \) to the output of the SD \( k \) using CC \( l \), and \( ε_{km}^l \) – from SD \( n \) to SD \( k \) using CC \( l \). To build a LAN cost function, we define the vector of parameters \( a = \{a_{is}\} \), \( c = \{c_{ij}\} \), \( r = \{r_{km}\} \) and \( w = \{w_i\} \), which we associate with the costs of using SS, PIC and SD models with various technical characteristics.

Analysis [11] showed the expediency of separating all cost parameters into two subsets. Let the first subset form a set of parameters that can be clearly specified \( \tilde{a} = \{\tilde{a}_{is}\} \), \( \tilde{c} = \{\tilde{c}_{ij}\} \), \( \tilde{r} = \{\tilde{r}_{km}\} \) and \( \tilde{w} = \{\tilde{w}_i\} \). To describe the latter, we will use the elements of the fuzzy sets theory and put in conformity with each fuzzy parameter the accessory function (AF) of the form "approximately equal to" or "is approximately in the range" \( \mu(\tilde{a}_{is}) \), \( \mu(\tilde{c}_{ij}) \), \( \mu(\tilde{r}_{km}) \) and \( \mu(\tilde{w}_i) \).

The physical connection of the PIC \( j \) of the variant \( q \) to the SD is possible if the PIC has active \( g_{j,q} \) network interfaces. The maximum number of connections to the SD SS, PIC and SD is limited by the permissible number of ports \( \bar{a}_{km} \) of the SD \( k \) with technical characteristics \( m \). In order to avoid packet loss, the total traffic of the \( f_{tp} \) channel \( \{t, p\} \) connected to the SD \( p \) must not exceed the bandwidth \( \bar{u}_{pm} \) of this SD. At the same time, the total traffic of each channel \( \{t, p\} \) must not exceed the bandwidth of the CC \( b_{tp} \) when it is implemented by type \( l \).

Therefore, the LAN structure must satisfy the following constraints.

1. Limitations on the technical capabilities of the PIC for connecting to them the SD:
   \[
   N_j(\{y_{j,q}\}, \{g_{j,q}\}, \{y_{jk}^l\}) \geq 0, j \in J.
   \]

2. Limitations on the technical capabilities of the SD to connect to them the SS, PIC and SD:
   \[
   N_k(\{c_{ij}\}, \{\beta_j^l\}, \{\varepsilon_{km}\}, \{\bar{a}_{km}\}) \geq 0, k \in K.
   \]

3. Limitations on traffic entering to SD:
   \[
   T_k^m(\{f_{ik}\}, \{z_{km}\}, \{\bar{u}_{km}\}) \geq 0, k \in K.
   \]

4. Restrictions on traffic in the CC between the SS and SD, PIC and SD, and SD and SD:
   \[
   T_k^m(\{f_{ik}\}, \{a_{ik}\}, \{b_{ik}\}) > 0, k \in K, i \in I_k;
   \]
   \[
   T_k^m(\{f_{kj}\}, \{\beta_j^l\}, \{b_{kj}\}) > 0, k \in K, j \in J_k;
   \]
   \[
   T_j^m(\{f_{jk}\}, \{y_{jk}^l\}, \{b_{jk}\}) > 0, j \in J, k \in K_j;
   \]
   \[
   T_k^m(\{f_{kn}\}, \{c_{kn}\}, \{b_{kn}\}) > 0, k \in K, n \in N_k.
   \]

We define the fuzzy criterion of LAN cost, in the form of a function \( F \), as the algebraic sum of the function \( F \) with clearly defined parameters and fuzzy \( \tilde{F} \):

\[
\tilde{F}(a, x, c, y, f, r, z, w, a, b, \gamma, e, d);
\]

\[
\tilde{F}(a, x, c, y, f, z, w, a, b, \gamma, e, d).
\]

Model research technology. The technology will be based on the results of [12]. Then the AF of fuzzy parameters can be represented as exponential functions. For example, for \( \tilde{a}_{is} \) an AF, that provides a value equal to 1 in \( \tilde{a}_{is}^\alpha \), will take the form \( \mu(\tilde{a}_{is}) = e^{-(\tilde{a}_{is} - \tilde{a}_{is}^\alpha)/\tilde{a}_{is}} \), where \( D_{is} \) is a parameter of the Gaussian fuzzy value \( \tilde{a}_{is} \). Therefore, the AF \( F \) will have the form:

\[
\mu(F) = e^{-{(F - m(x,y,z,a,b,\gamma,e))}^2/2D(x,y,z,a,b,\gamma,e)}.
\]

If to suppose that it is required to get such alternative, the generalized characteristic of which as a level of belonging of decision must be not worse than the predetermined value \( \theta \), we equate \( \mu(F) \) to \( \theta \). Using classical transformations, we get:

\[
(F - m(x,y,z,a,b,\gamma,e))^2 = -2D(x,y,z,a,b,\gamma,e)ln\theta.
\]

Following the optimistic scenario of the synthesis of the LAN structure, the cost criterion \( F \) can be represented as:

\[
m(x,y,z,a,b,\gamma,e) - (-2D(x,y,z,a,b,\gamma,e))^{0.5}.
\]

The pessimistic scenario should comply with the cost criterion \( F \), defined follows:

\[
m(x,y,z,a,b,\gamma,e) + (-2D(x,y,z,a,b,\gamma,e))^{0.5}.
\]

Then, by optimizing the obtained function \( F \) with the limitations of the model for the synthesis of the LAN structure, we can find an alternative \( (x,y,z,a,b,\gamma,e) \), providing the decision maker with information about the network structure, its cost and the level of the decision not worse than \( \theta \).

Conclusion. The paper deals with the problem of formalization and the study of uncertainty. Probabilistic-statistical, interval, fuzzy and deterministic approaches are analyzed. The problem of the synthesis of the LAN structure in the conditions of uncertainty of the initial information is formulated. The model for the synthesis of the LAN structure formalizes the uncertainty using a fuzzy approach. The model research technology illustrates the peculiarities of solving the problem of LAN structure synthesis in fuzzy formulation.

Further studies will focus on the analysis of approaches to solving problems of structural-topological synthesis of LAN and the development of appropriate software solutions.

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