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MODEL OF DATA FLOW CONTROL SUBSYSTEM OF THE MANET CLASS MOBILE RADIO NETWORK CONTROL SYSTEM

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Summary. *The article proposes a model of the data flow control subsystem of MANET class mobile radio control system to evaluate the effectiveness of the model, which will be built based on the developed methods and techniques (corresponding units). The essence of the model is to apply appropriate methods of DFCS control, which interact with each other and other functional subsystems within the operation of the subsystem units and their interaction, based on the target function. To ensure effective control of a mobile radio network in conditions of frequent changes of the situation (operational, tactical, communication, etc.) is possible only if there is a nodal control system capable of making control decisions in conditions of uncertainty. In addition, provision of the ability of mobile radio networks to self-organization, as well as adaptation of its nodes to different operating conditions requires the presence of a training subsystem as part of the node control system. To ensure effective control of a mobile radio network in conditions of frequent changes of the situation (operational, tactical, communication, etc.) is possible only if there is a nodal control system capable of making control decisions in conditions of uncertainty. In addition, provision of the ability of mobile radio networks to self-organization, as well as adaptation of its nodes to different operating conditions requires the presence of a training subsystem as part of the node control system. Considering the peculiarities of the functioning of MANET class radio networks, the article proposes to intellectualize the control processes by using knowledge processing technologies in the construction of a node control system. Based on the integrated use of fuzzy logic and neural networks, the probabilities of violations are considered, which, depending on the parameters of the state of the nodes, allow selecting the required value of the violation of the state of the network. Unlike existing models that are used in computer or fixed networks that do not require resource-intensive structure, in this model it is proposed to develop the structure of the DFCS to the requirements and features of usage in the mobile radio network. The application of the model will allow: to simplify and improve the structure of the construction of the data flow control subsystem; to process incomplete, inaccurate, unpredictable, different in its physical content data; to reduce the time of making a control decision. The further directions of research will be the development of the method of connectivity of the elements of the data flow control subsystem of the mobile radio network control system.*

Key words: *mobile radio network, MANET, control system, data flows, intellectualization, neuro-fuzzy network.*

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Statement of the problem. The control of radio networks and nodes in the modern conditions of development of information and communication systems requires timely and complete obtaining of information on the situation prevailing in the node or network, at any given time. Collection, processing, analysis, and adoption of appropriate control decision is possible through the use of modern radio networks, which can provide communication at any place in any time. MANET (Mobile Ad-Hoc Network) mobile radio networks (MR) are an example of such networks [1].

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The operation of these networks is characterized by the mobility of all nodes, as well as the ability to self-organize into a radio network without pre-deployed network infrastructure under conditions of uncertainty. In MR, the transmission of information between the sender and the addressee can be carried out both directly and by retransmission through intermediate nodes. The main condition for successful transmission or reception of information between two nodes is the presence of an effective control system (CS), which operates on each node of the MR [2].

Considering the full mobility of all elements of the MR (both nodes and base transceiver stations), effective control is possible both by controlling the power of transmitters and by choosing the optimal routes for data transmission between the nodes. In both cases, there is an urgent task, which is to choose the control decisions that would, on the one hand, provide the transmission of information to the MR with a given quality of service, and on the other – minimize the resource costs of mobile nodes.

Considering the conditions of uncertainty, dynamic topology, the presence of heterogeneous in its physical content data, which characterize the operation of the MR, and the unpredictability of the network environment, to solve this problem, we propose to use the hierarchical-distributive structure of the data flow control subsystem (DFCS) of the CS using the apparatus of fuzzy logic and neural networks (NN).

Accordingly, the **objective** of the article is to develop a model of the data flow control subsystem of the MANET class mobile radio network control system for evaluating the operation of separate elements of the model and the model as a whole. The object of study is the process of information transmission in MANET class MR. The subject of research is the model of the data flow control subsystem of the control system of mobile nodes in MR.

Analysis of available research. Depending on the topology of the MR, which is determined by the organizational structure of subdivisions during the battle, the transmission of information between the sender and the addressee in the MR can be carried out both directly and by retransmission through intermediate nodes using predefined data transmission routes [3]. However, in any case, in the MR, successful transmission between two nodes can occur only with the effective operation of the DFCS of the node CS. In its turn, interruptions in the operation of the DFCS can lead to: overloading of the system; loss of information during transmission; impossibility of organizing communication between nodes; breaking the existing data transmission route.

Since the DFCS must ensure the control of data flows of nodal CSs [4, 5], the DFCS must monitor all traffic circulating in the MR. For this purpose, the DFCS ensures its operation at all levels of the OSI model, and at the same time performs: connection control, analysis of the structure and content of network packets, traffic control, etc. Overloading of data flows, blocking the node, hidden control of nodal and network resources or affecting the information, software and hardware of the nodal CS can serve as the aim of violating the operation of the DFCS of the CS [6].

The violation is defined as an impact on the properties of the MR (architectural or another flaw), which can be used to access the DFCS, the CS or the MR. In meanwhile, the vulnerability is a characteristic of the effective operation of the nodal CS, and any vulnerability of the network carries the threat of affecting its components. These violations affect the MR and its components that ensure the transmission of information in accordance with the functional characteristics of each network object. The threat is realized at all levels of the OSI network model and can affect the network object from the outside (data flow, communication node, radio repeater, end device), as well as from the inside (data traffic, software, and hardware of the network) [7].

Let's consider the current existing CSs; data flows and their functional features. In [8] the scheme of automated data flow control is considered (Fig. 1).

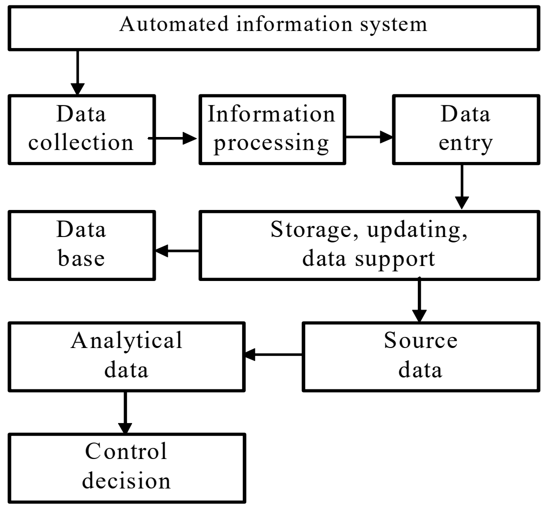

Figure 1. Structural diagram automated management of date flows

The automated system provides control of access to information and technical resources, as well as the possibility for different categories of users to work with heterogeneous information. Data collection is based on the use of agents within its own subsystem. Information processing can be carried out autonomously in computer networks using a set of software tools and information arrays to solve functional problems. While solving problems, relevant analytical data and reports are generated. The system uses a step type regulator. The main components of the system include the units shown in (Fig. 1). The decision-making unit makes a control decision based on the expert list.

In [9], the scheme of intelligent control of data flows is considered (Fig. 2).

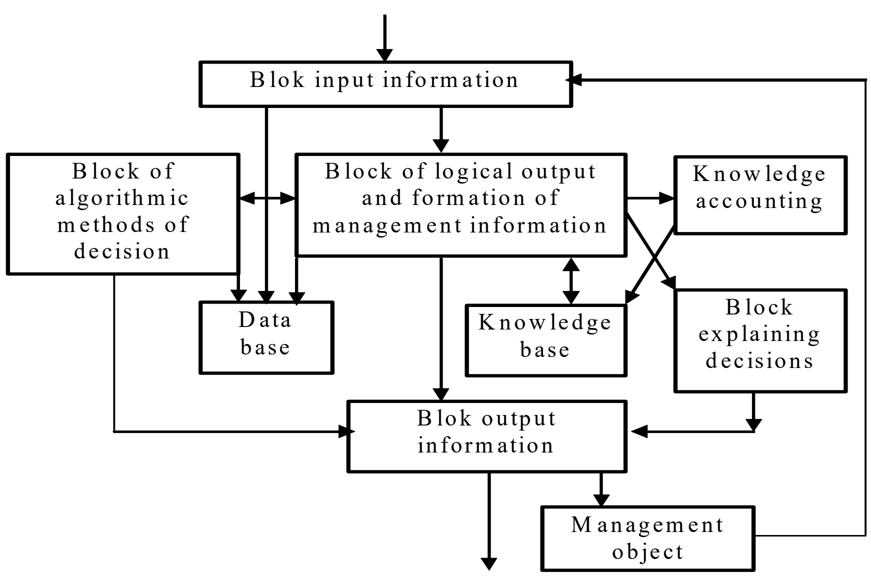

Figure 2. Structural scheme of intelligent control of data flows

Based on the structure of its construction and functional features of the system elements, the SC is intelligent. However, the application involves the presence of large resource loads. Data collection is based on the usage of intelligent agents within its own subsystem. By the way of interaction, this system is a system with unpredictable reactions. By the level of intelligence, the system belongs to systems – by intelligence «in small». In this system the parallel type of regulator is used. The output unit makes a control decision based on the expert list. In general, the main drawbacks of these models include: usage in computer or stationary networks; atypical functional structure for usage in MR; the usage of algorithms that involve complex calculations, which requires large resource reserves of nodes (stations); the availability of algorithms that require direct sequence of actions using functionally limited units, which increases the decision-making time.

Taking this into consideration, to develop a model of the DFCS of control system for usage in the MR it is expedient to use a combination of existing approaches and their appropriate adaptation. Based on the mentioned above, we will put forward the requirements for the model under development, namely: the availability of technology of intellectualization in the decision-making process; simplicity of construction and resource ease of the nodal CS; decentralized, hierarchical and distributive structure of the DFCS construction; the ability to process incomplete, inaccurate, diverse in their physical content data; application in conditions that characterize the operation of the MR; reducing the time of making a control decision of the DFCS; interaction with other functional control subsystems etc.

Statement of the problem. In the MR control system, the DFCS, which interacts with other functional control subsystems, is used. The structure of the DFCS is hierarchical and distributive. Due to the impossibility of collecting information in real time (predictable, accurate, complete, clear) about the state of the MR, we will consider the process of data flows routing in the information direction, which consists of end nodes, as well as a multitude of nodes that form data transmission channels between them. The set of requirements for the model: {Bq} = {B1, B2, B3} is: work in conditions of decentralized control; minimum network load with service information; the ability to interact with different levels of the OSI model.

It is necessary: to develop a model of the DFCS of the MR control system to evaluate the effectiveness of the model, which will be built on the basis of the developed methods and techniques (corresponding units).

Analysis of the results. Considering the aforesaid analysis of the existing models and requirements for the model that should function in the MR, a new model of the DFCS of the MR control system is proposed. Its purpose is to apply appropriate methods of DFCS control, which interact with one another and other functional subsystems within the operation of the subsystem units, and their interaction based on the target function.

The proposed structural diagram of the MR control system is shown in (Fig. 3), and consists of:

- Traffic identification unit – is an intelligent identification of traffic in MR. The point is to technically identify the parameters of MR traffic by neurons of NN with the training of the network without a teacher based on backpropagation of the newly discovered values of traffic parameters. The identifier will allow: to increase the efficiency of MR operation by using the neuro-fuzzy inference system to control data flows.
- Unit of evaluation of operation state – is an evaluation of the level of operation of the mobile radio network control system from destructive actions. This unit provides evaluation of the level of operation of the MR based on a number of parameters that reflect the operation of the elements of the MR with the function of parallel and distribution identification of new types of violations and taking into account the strategies of their impact on the MR, using the method of dynamic programming and the algorithm of distribution identification by the least squares method.

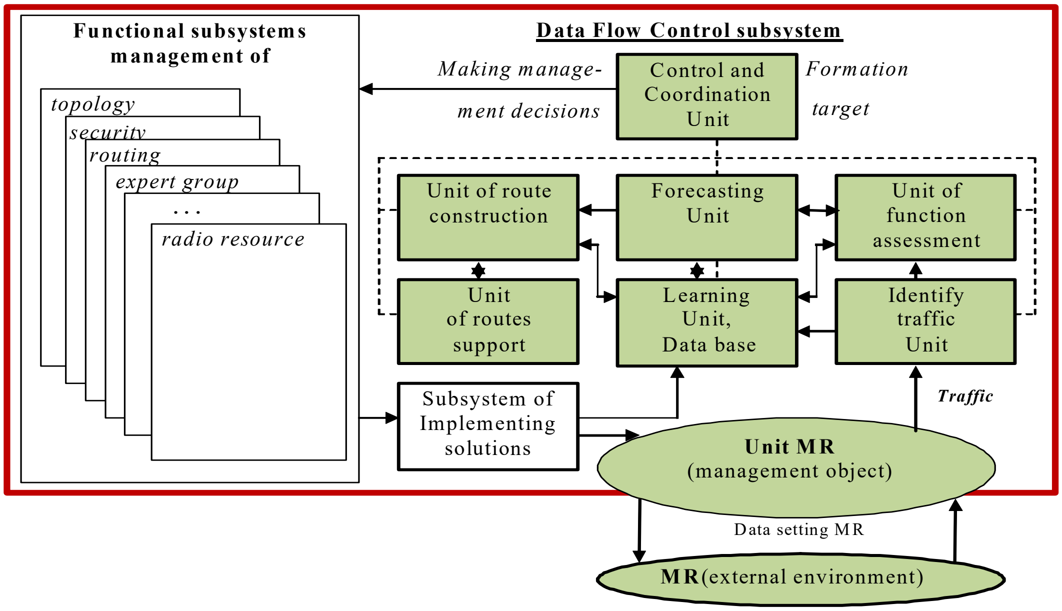

Figure 3. Structural diagram of the MR control system

- Learning unit, database – is an intellectual training of knowledge bases (KB) of the DFCS of the MR based on NN. The essence of training is to distribute the process of designing, building, choosing the structure of the KB and the process of obtaining knowledge by the intellectual knowledge base of the DFCS, taking into account the peculiarities of the operation of the MR based on NN. In the process of training, it is proposed to distribute the process of building the KB, taking into account the dynamic and unpredictable nature of operation of the MR based on the relational structure of the fuzzy product knowledge base of the CS, which implements the fuzzy inference algorithm ANFIS. The application will simplify and systematize the process of designing, building, selecting the structure of the KB, the process of obtaining knowledge and modeling the elements of the nodal CS in the MR, as well as it will allow more effective application of methods of controlling the nodal CS at the levels of the OSI model.
- State prediction unit – is a prediction of the time of overloading data transmission routes in the MR which is built using NN based on the calculation of its potential. The prediction unit considers the need for decentralization of control; decision-making under uncertainty; reduction of time for making control decisions. The application will allow predicting the time of overloading of data transmission routes in the MR by reducing the computational complexity of the NN and the usage of the NN training algorithm.
- Unit of data routing – is the construction of data transmission routes by selecting data parameter metrics, considering the specific features of the operation of telecommunication networks. The idea is to introduce a hierarchy of the decision-making process for designing a data transmission route in order to ensure a given quality of service for certain types of traffic under different conditions of operation of telecommunication networks using a hybrid structure of the unit. The application will allow to build routes of a specified quality, to reduce the volume of service traffic, to increase the bandwidth of the information direction.
- Block of data transmission routes support – is the support of data transmission routes (DTR) in the MR. Its operation is based on fuzzy logic and genetic neural algorithm, which

allows by means of controlling and distributing the residual battery capacity to increase the lifetime of the DTR and reduce the loading of network channels, which results in a decision to support the DTR in the network and increases the network lifetime. The idea is to use fuzzy logic and genetic neural algorithm that allows to reduce the loading of network channels by controlling the traffic and distribution of residual battery capacity, which results in a control decision to build the DTR in the network and increase the time of operation of the MR.

- Control and coordination unit - represents the control decision-making, coordination of actions between the elements of the DFCS and the formulation of the control goal based on the analysis of the parameters of the node state and the parameters of the network operation, which are set in the form of fuzzy variables, which indicate: target control functions; routing method; number of addressees; type of routing; reliability and safety requirements; type of radio channels; network dimension; control goal; routing function; MR format; method and depth of data collection or sending; type of traffic parameters of interaction with other elements of the CS. In general, the decision-making process is reduced to the problem of fuzzy multicriteria optimization [10, 11].

Based on the functional features of the proposed units, it is noticeable that an intelligent platform serves as the basis of the DFCS of the MR control system, which is represented by the usage of NN, which in turn will satisfy the requirements for building a model and will allow to build a structured, hierarchical and distributed subsystem with the possibility of decentralization of functions [12].

Since the DFCS operates at all levels of the OSI model, and violations of the state of the DFCS elements are equivalent for all levels of the OSI model, it is advisable to determine the probability of occurrence of violations of the operation at the levels of the OSI model. At the same time, each level of the OSI model will have its own value of the violation coefficient, based on: data parameters at a single level of the OSI model; statistical data on the impact on each level; the capabilities of the DFCS to detect violations, etc.

The value of the probability of violation of the state of operation of the DFCS at a single level of the OSI model in general will be as follows:

$$R = P_z \cdot P_v \cdot \varpi, \quad (1)$$

where: P_z is probability of violation of the state of operation of the DFCS at single level of the OSI model; P_v is probability of exploiting the vulnerabilities of the CS at a single level of the OSI model; ϖ is the coefficient of violation of operation at a single level of the OSI model.

The probability of violation of operation of the elements of the DFCS at a single level of the OSI model for a certain time t can be carried out by types of violations j_z at a certain frequency λ. Thus, it is expedient to split the time t into x equal parts. Then the probability that a violation will occur at a time interval will be determined by:

$$P_t = \lambda t / x , \quad (2)$$

In order to get a complete picture of the state of DFCS operation at a single level of the OSI model, it is necessary to take into account the DFCS objects in which violations of the DFCS operation can be established. Therefore, the implementation of options for violations on DFCS facilities can be described by the law of probability. The facilities to which this probability may be applied include:

$P(z/l)$ – probability of a violation z at a single DFCS facility l;

$P(z/\sum l)$ – probability of a violation z at a multitude DFCS facilities l
$P(\sum z/l)$ – probability of a multitude of violations z at a single DFCS facility l;
$P(\sum z/\sum l)$ – probability of a multitude of violations z at a multitude DFCS facilities l

That is:

$$P(z/l): z \to l; \tag{3}$$

$$P(z/\sum l): z \to \sum l; \tag{4}$$

$$P(\sum z/l): \sum z \to l; \tag{5}$$

$$P(\sum z/\sum l): \sum z \to \sum l. \tag{6}$$

Therefore, the probability of violation of the operation of DFCS facilities will be calculated:

$$P(z,l) = \prod_{i=1}^{l} P_i^z. \tag{7}$$

The probability of violation of the operation of DFCS facilities at a single level of the OSI model will be determined by the probability that the violation will be carried out at a time interval $1/t$. According to Poisson's law, we will obtain the expression:

$$P_k = 1 - e^{-\lambda/t}. \tag{8}$$

The probability of violations k during time t will be distributed according to Poisson's law. Therefore, as a hypothesis of the law of distribution of violations, we accept the Poisson distribution law, and the average value of violations will be determined by:

$$Y = \frac{1}{x}\sum_{i=1}^{x} y_i, \tag{9}$$

where y_i is the value of a random variable on the i -th time interval at x - number of time intervals.

Conclusions. The paper presents a DFCS model of the MANET class MR control system. The model is to apply appropriate methods of DFCS control, which interact with each other and other functional subsystems within the operation of the units of the subsystem, and their interaction based on the target function. Unlike existing models that are used in computer or fixed networks that do not require resource-intensive structure, in this model it is proposed to develop the structure of the DFCS to the requirements and features of usage the MR. The application of the model will allow: to simplify and improve the structure of the construction of the DFCS; to process incomplete, inaccurate, unpredictable, different in its physical content data; to reduce the time of making a control decision. The further directions of research will be the development of the method of connectivity of the elements of the DFCS of the MR control system.

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МОДЕЛЬ ПІДСИСТЕМИ УПРАВЛІННЯ ПОТОКАМИ ДАНИХ СИСТЕМИ УПРАВЛІННЯ МОБІЛЬНОЇ РАДІОМЕРЕЖІ КЛАСУ MANET

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Резюме *Запропоновано модель підсистеми управління потоками даних системи управління мобільної радіомережі класу MANET для проведення оцінювання ефективності функціонування моделі, яка буде побудована на основі розроблених методів та методик (відповідних блоків). Суть моделі полягає в застосуванні відповідних методів управління підсистеми управління потоками даних, які взаємодіють між собою, та іншими функціональними підсистемами в рамках функціонування блоків підсистеми, їх взаємодії, виходячи із цільової функції. Для забезпечення ефективного управління мобільної радіомережі в умовах частої зміни обстановки (оперативної, тактичної, зі зв'язку тощо) можливе лише за наявності вузлової системи управління, здатної приймати управляючі рішення в умовах невизначеності. Крім того, забезпечення здатності мобільних радіомереж до самоорганізації, а також адаптації її вузлів до різних умов функціонування вимагає наявності підсистеми навчання у складі вузлової системи управління. Враховуючи особливості функціонування радіомереж класу MANET, запропоновано інтелектуалізувати процеси управління шляхом використання технологій опрацювання знань при побудові вузлової системи управління. На основі комплексного використання нечіткої логіки та апарата нейронних мереж, враховано ймовірності здійснення порушень, які, залежно від параметрів стану вузлів, дозволяють вибрати необхідне значення порушення стану функціонування мережі. На відміну від існуючих моделей, які застосовуються в комп'ютерних або стаціонарних мережах. Що не потребують ресурсно-необтяжливої структури, в даній моделі запропоновано розроблення структури підсистеми управління потоками даних до вимог та особливостей використання в мобільних радіомережах. Застосування моделі дозволить: спростити й удосконалити структуру побудови підсистеми управління потоками даних; проводити опрацювання неповних, неточних, непередбачуваних, різних за своїм фізичним змістом даних; зменшити час прийняття управлінського рішення. Подальшими напрямками досліджень буде розроблення методу зв'язності елементів підсистеми управління потоками даних системи управління мобільної радіомережі.*

Ключові слова: *мобільна радіомережа, MANET система управління, потоки даних, інтелектуалізація, нечітка логіка, нейронні мережі.*

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