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PRINCIPLES AND STRUCTURE OF THE METHODOLOGY OF RISK-ADAPTIVE MANAGEMENT OF PARAMETERS OF INFORMATION AND TELECOMMUNICATION NETWORKS OF CRITICAL APPLICATION SYSTEMS

The **subject matter** of the article is the processes of structural synthesis and parametric analysis of information and telecommunication networks (ITN). The **aim** is to develop the methodological apparatus which will enable obtaining ITN structural and technical parameters in order to ensure the operation of safety-critical systems (SCS), adaptive to external conditions and resistant to risks. The **tasks** to be solved are: to formulate principles and definition of the structure of the risk-adaptive management methodology of ITN SCS parameters; to determine the composition of the methodical apparatus and the applied means of the suggested methodology. General scientific **methods** used are: system analysis, structural and parametric synthesis, methods of decomposition and aggregation, methods of risk-adaptive management. The following **results** are obtained. The diagram of the main stages of ITN analysis is presented. In this case, the elements of the distributed architecture of ITN SCS are defined. The requirements for calculating the characteristics of the information and technical structures of the network are listed. The ways of fixing SCS applications at the functional nodes of the network are considered. The steps that are performed at the stage of solving the task of network setting are defined. The stage of matching task settings and operational management is a part of adaptive control. The above steps of analysis, synthesis and management of ITN are the basis of the structure of the risk-adaptive ITN SCS management methodology, which includes the following elements: principles, models, methods, and applied means. The methodology is based on the principles of decomposition, matching of goals and coordination of management, stream analysis and modeling of processes, adaptive and risk-based management. The composition and peculiarities of models (mathematical and systemic) and methods which are the basis of the methodical apparatus are determined. The applied part of the methodology is implemented by the information technology of adaptive management of distribution of network traffic. On ITN basis, the problem of interaction of technical and software means in the management of traffic distribution and organization of collecting, processing and transmitting information in the management system is solved. Adaptive management is provided by solving the tasks of setting the mode. Risk orientation is represented by two contours of feedback, which involves assessment and risk management at the stages of structural and parametric synthesis and distribution of network traffic. **Conclusions**. The implementation of the suggested methodology for ITN synthesis and management will enable the operation of SCS that is adaptive to external conditions and risk-resistant, which contributes to the improvement of the system safety.

Keywords: information-telecommunication network, risks, adaptive management, information structure, parameters, methodology.

Introduction

The development of high technology results in the enhancement of high-risk facilities that belong to safety-critical systems (SCS), for example, thermal, nuclear and hydroelectric power plants in the energy sector, high-speed ground and air transport as well as defense and space systems.

Safety-critical systems are characterized by high intensity of information streams; the requirements for efficiency management, and timely making decisions and bringing them to actors are rather high. SCS operation is impossible without the use of high-speed multiservice information and telecommunication networks (ITN). However, SCS have very high demands on both network performance and the reliability of service.

The above factors are connected with the task of SCS functional safety. To solve this problem systematic analysis and risk assessment of information and telecommunication networks (ITN) should be conducted for further assessment of the damage and making decisions on risk parry.

Fulfilling these requirements is closely linked with the necessity of generalization of the accumulated global experience in the sphere of information communication and depends on the use of advanced information technologies related to data processing.

Problem setting

Despite the rapid development of technology of physical and channel level, ITN potential can be fully implemented only with the help of effective management of available network resources amid increasing efficiency requirements for information exchange. These factors determine the necessity of new approaches to determining physical and functional network architecture.

A lot of publications [1–5] are devoted to the problems of ITN analysis and synthesis. However, considering the network structure just as a set of nodes and connections among them do not enable examining data streams.

Classical mathematical models based on the results of using graph theory and queuing theory [2, 3], do not consider the dependence of network structure characteristics on the parameters of applied problems solved in the network environment, which leads to the loss of accuracy of simulation results.

One of the promising areas of ITN development is the service-oriented approach that enables examining the exchange of information among network nodes that are involved in solving various problems and provide various information services. However, formalizing data streams is insufficient in the context of this approach and is limited by specific simulation tasks and aspects of ITN operation [4, 5].

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The information safety of telecommunication systems is affected by various threats from viral infection to the legal conflicts. Hence, there are risks that can create a negative impact on the characteristics of ITN operation.

Today the problem of ITN protection is governed by the standards of Information Technical Laboratory (ITL) at the National Institute of Standards and Technology (NIST). Some literature sources deal with the problems of vulnerability analysis and ITN risk assessment, information safety and protection [6]. The classification of network attacks, threats to information safety is carried out and the ways of their detection are determined [7]. The problems of making decisions on the management of networks information safety are considered [8, 9]. However, most scientific researches in the field of the assessment of information risk (IR) have not carried out the systematic consideration of IR causes, factors and interactions with the other types of ITN risks; the classification of the causes and risk factors at the stage of ITN synthesis and analysis as well as while planning network traffic has not been performed.

The above aspects and challenges, existing mathematical means of analysis and synthesis in ITN SCS require developing appropriate methodological apparatus, the use of which will enable receiving ITN structural and technical parameters for the operation of SCS adaptive to external conditions and resistant to risks. Thus, the purpose of this paper is to formulate principles and determine the methodology of risk-adaptive management of ITN SCS parameters.

Principles and the structure of the methodology of ITN risk - adapted management

Information and technical support of SCS contains a number of hardware, software and other means that are combined structurally and functionally to provide one or more types of information processes. Modern SCS are characterized by hierarchical, functional and resource distribution (servicing, software and hardware, telecommunications), by a great number of interacting components, blocks, subsystems, complex management system. Thus, SCS are complex technical systems that operate amid random factors, in the context of active interaction with the environment, negative impacts and under high cost of consequences of probable failures or errors in the system operation [10].

Let us consider the diagram of ITN SCS analysis (fig. 1) [11].

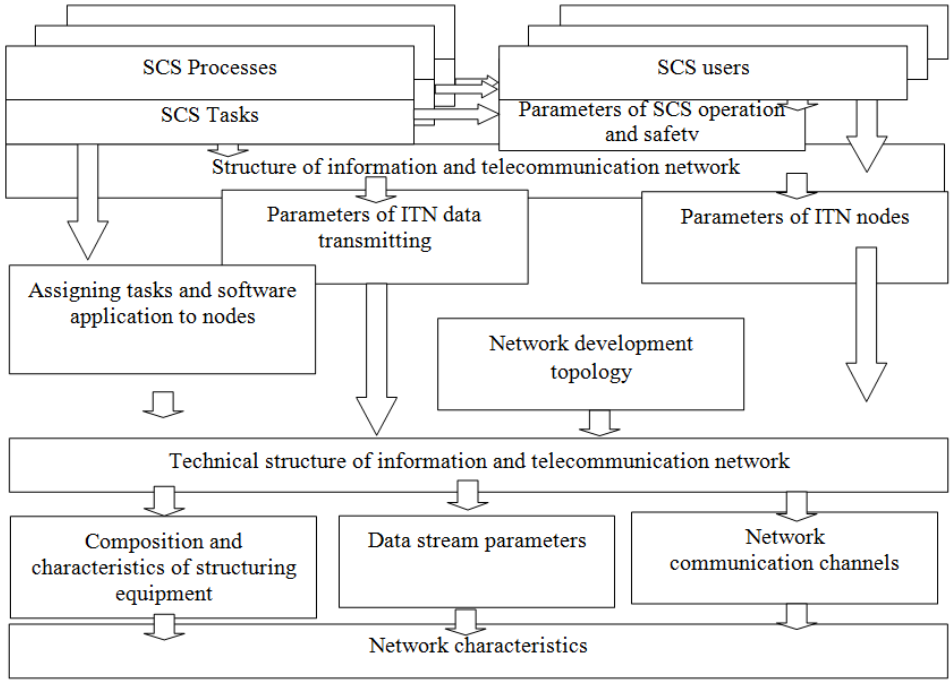

Fig. 1. Diagram of analyzing SCS information and telecommunications network

The first step is to analyze the object, i.e. SCS, where it is necessary to determine:

- the composition and parameters of applied tasks in order to ensure system operation,
- a number of ITN users,
- a set of applications installed in the network and hardware requirements in order to implement applications.

The next stage is to develop ITN structure. Let us consider the basic structural elements of the network.

The elements of the distributed architecture of ITN SCS are:

- data center, which is responsible for storing and processing all the data of the information system and implements a part of software applied logic at the central level,
- backup data center that provides fault tolerance by storing data of the entire system,
- custom (client) software for implementing a part of applied logic, data visualization and users' interaction with the system;
- database server and application servers at the nodes that are responsible for storing, processing all the data at a

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particular node and implement a part of software applied logic at the node level, and additionally provide data sharing with other levels.

The necessary elements of ITN centralized architecture are: a telecommunication network, a system of information protection, servers for data exchange.

Both information and technical characteristics should be determined for these elements; to do that it is necessary:

- to analyze the information network structure;
- to determine indicators and quality criteria for solving applied problems;
- to determine the composition of the network parameters that will be used for network management and development of network state space.

ITN structure is the main factor affecting the quality of data exchange among software applications and, consequently, the quality of solving applied tasks. Therefore, the analysis of the structure is a prerequisite in selecting variants of information and telecommunications network development and ITN management.

The main purpose of the structure analysis is to determine the parameters of data streams that pass through the communication network and enter ITN nodes. These data make it possible to assess the load of communication channels and network equipment. Besides, for the network analysis information about the net structure should be supplemented with the information about software applications, their interaction and assignment to the nodes.

In distributed SCS applications can be assigned to functional nodes in different ways:

- one application is broken down into components that are run at several nodes (vertical distribution), while data processing is distributed hierarchically;
- one application is duplicated at several nodes (horizontal distribution);
- different applications are distributed among several nodes.

The results of analysis of ITN parameters are quantitative values of such characteristics, loading at the communication channels and structuring equipment, intensity of data streams and data requests that enter the network nodes. In this case the mentioned characteristics should be calculated taking into account the specific characteristics of the network structure.

When the above procedures are completed the task of traffic distribution management can be solved. At the stage of solving the problem of network settings, the following steps should be made:

- defining specific indicators of quality of network settings;
- developing and calculating parameters of data streams of hierarchical information structure of the network;
- determining the composition of network equipment;
- developing technical structure of the network.

When this stage is over there appears a variant of network structure. The level of ITN operation risk which is necessary for assessment of parameters of SCS safety should be assessed for the obtained structure taking into account the calculated parameters. If the risk level is too high due to internal factors, the methods of ITN reengineering are used. Otherwise, the next stage is to be completed, that is solving the tasks of operational management of ITN SCS subsystems.

The stage of correcting setting tasks and operational management is a part of adaptive management, it takes place when basic network settings are changed and can hinder reconfiguring the network and developing new approaches to solving problems of operational management. It includes the correction of:

- the composition of network parameters,
- the composition of basic parameters and the parameters of management,
- quality requirements for solving applied problems.

These steps are necessary as a way to parry external risks that affect the network operability and respectively the system safety.

The above steps of analysis, synthesis and ITN management are the basis of the structure of the methodology of risk-adaptive management of ITN SCS.

The general structure of the methodology includes the following elements (Fig. 2):

- principles;
- models;
- methods;
- applied means.

The basis for formulating general principles of the methodology are the features of the object (SCS) and the methods of ITN analysis and management. The methodology is based on the following principles:

- decomposition,
- matching tasks and coordination of management,
- stream analysis and process modeling,
- adaptive management,
- risk-based management.

The principle of decomposition is caused by the distributed structure of SCS and the tasks of traffic distribution, which leads to splitting the system into a number of subnets.

The principle of matching tasks and management coordination is carried out when the distribution of traffic for each subnet is made taking into account the state of other subnets. Besides, it is necessary to match the goals of subnet management, when local goals of traffic distribution management objectives in separate subnets should ensure achieving global goals of network management.

The principles of stream analysis and simulation are fulfilled while solving the tasks of measuring, modeling, traffic parameters description in order to obtain necessary network performance.

The principle of adaptive management ensures the efficient use of network resources.

To increase the safety of information resources the approach to the development of adaptive safety systems is used, which focuses on the active opposition to safety threats [14, 15]. Implementing this approach requires risk analysis, developing safety policies, using traditional protection means, and implementing counter measures to meet threats, ongoing safety auditing and monitoring the state of the system that should enable quick respond to ITN risks. Therefore, the principle of risk-based

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management is used; this principle reflects the problem of analysis and risk assessment in order to make decisions on their parrying (both at the level of structural synthesis and at the level of operational management), thereby increasing the safety of the systems. The main means that are used to parry risks in adaptive systems of management are active agents: intrusion detection sensors, abnormal behavior recognition algorithms, adaptive algorithms of recovery.

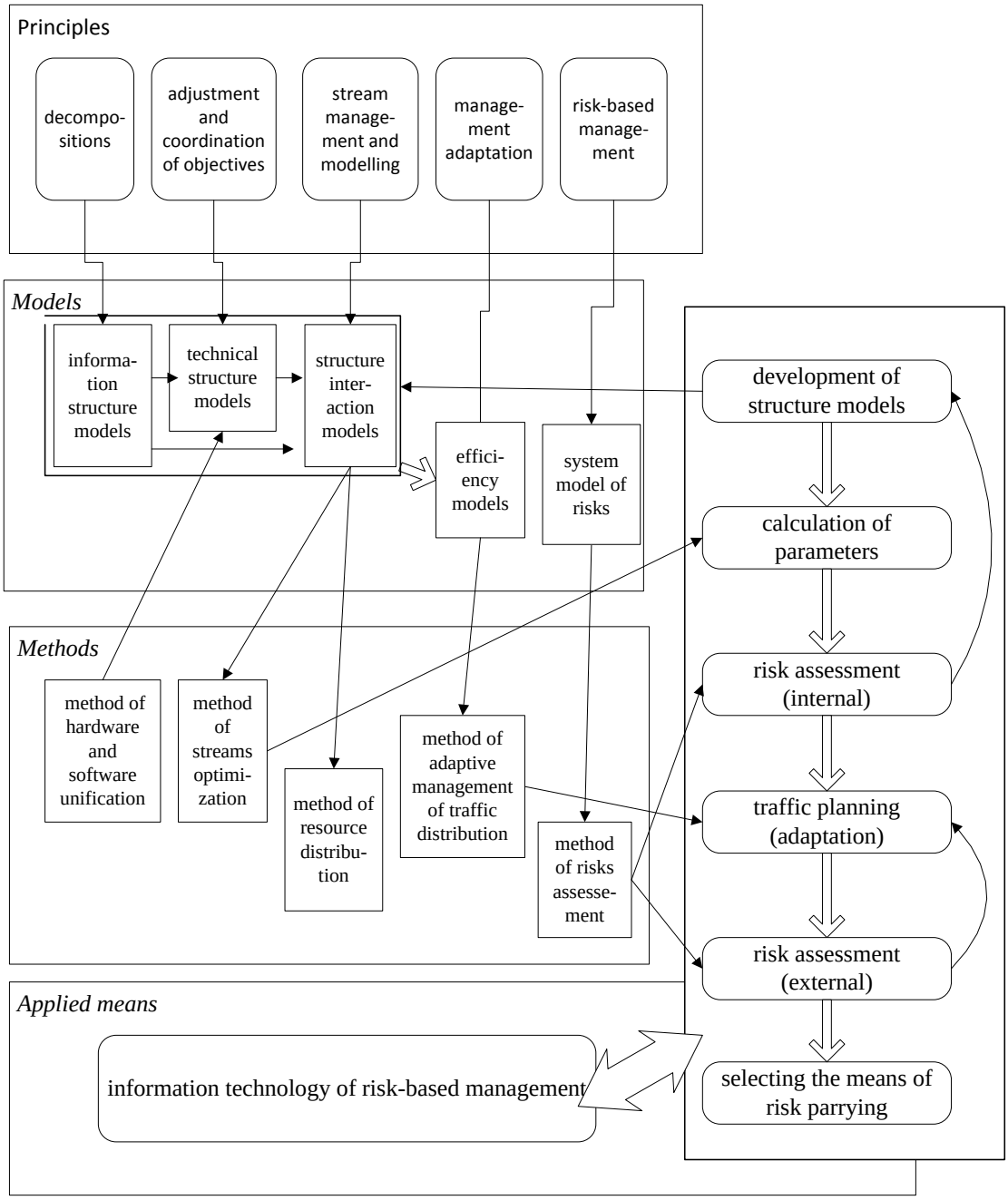

Fig. 2. The methodology of ITN risk-based management

The mathematical apparatus for analyzing ITN structure is the complex of models that includes:

1) mathematical model of information network structure,

2) mathematical model of technical structure of the network in order to determine the parameters of hardware and software components of ITN,

3) mathematical model of information interrelations among network elements which takes into account the intensity of requests to system applications; the model describes the relationship between the informational and technical structures of the network;

4) model of the main factors and the criterion of the efficient use of network resources for using in the methods of ITN adaptive management;

5) system model of ITN risks.

The methodological apparatus of the suggested technique comprises the following methods:

1) the method of unification of software and hardware-based applications which is based on the use of

repetition-free algorithmic structures and is used while technical analysis of the network structure;

2) the method of assessing stream deflection for the alternative procedure of route selection in order to determine optimal streams and the most efficient routes in ITN,

3) the method of distributing the resources of multi-server node of data processing which is based on the model of the network structure and information as for bandwidth distribution among the used channels;

4) the method of adaptive management of traffic distribution, which helps solve the problems of configuration and operational management, management of distributing the communication channel bandwidth, distributing the resources of multi-server node of data processing;

5) the method of assessing ITN risks and their impact on SCS safety performance.

Applied means of the methodology are implemented by the information technology of adaptive management of traffic distribution. On ITN basis the problem of hardware and software interaction while using different methods and algorithms of traffic management and development of the diagram of organizing, collecting, processing and transmitting in the management system is solved. Besides, the assessment of ITN parameters that were obtained with the help of the methods that take into account the features of data streams is carried out. In the information technology algorithmic means of the control of ITN technical state are implemented.

To parry the risks and to ensure SCS safety the following mechanisms should be available [12, 14]:

- the mechanism of monitoring the system state and environmental impact;
- the mechanism of adaptation in the context of little change of conditions for optimization of the system operation according to the defined criteria;
- the mechanism of restoration after failures, faults, errors;
- the mechanism of redistribution of system resources to fulfill the goals of ITN operation in a new environment.

Conclusions

The diagram of ITN SCS analysis became the basis for developing the structure of the methodology for risk-adaptive management. The main structural elements of ITN are determined, both information and technical characteristics are specified. Different ways of assigning applications to functional network nodes are considered.

The essence of the principles of the suggested methodology is formulated and revealed. The composition of models (mathematical and system) that are the basis of methodological techniques are determined. Management adaptability is provided by solving the problems of network settings. Risk-orientation is displayed by two feedback circuits, where assessment and risk management at the stages of structural and parametric synthesis and distribution of network traffic are provided.

The implementation of the suggested methodology for ITN synthesis and management will enable the operation of SCS, adaptive to the environment and resistant to risk, thereby increasing the system safety.

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ПРИНЦИПИ І СТРУКТУРА МЕТОДОЛОГІЇ РИЗИК-АДАПТИВНОГО УПРАВЛІННЯ ПАРАМЕТРАМИ ІНФОРМАЦІЙНО-ТЕЛЕКОМУНІКАЦІЙНИХ МЕРЕЖ СИСТЕМ КРИТИЧНОГО ЗАСТОСУВАННЯ

Предметом дослідження в статті є процеси структурного синтезу та параметричного аналізу інформаційно-телекомунікаційних мереж (ІТМ). **Мета** – розробка методологічного апарату, застосування якого дозволить отримувати структурні та технічні параметри ІТМ для забезпечення функціонування систем критичного призначення (СКП), адаптивного до зовнішніх умов та стійкого до ризиків. **Завдання:** формулювання принципів та визначення структури методології ризик-адаптивного управління параметрами ІТМ СКП; визначення складу методичного апарату та прикладних засобів пропонованої методології. Використовуються загальнонаукові **методи:** системний аналіз, структурно-параметричний синтез, методи декомпозиції та агрегації, методи ризик-адаптованого управління. Отримано такі **результати**. Наведено схему основних етапів проведення аналізу ІТМ. При цьому визначено елементи розподіленої архітектури ІТМ СКП. Перелічено вимоги для розрахунку характеристик інформаційної і технічні структур мережі. Розглянуто способи закріплення додатків СКП за функціональними вузлами мережі. Визначено кроки, які виконуються на етапі вирішення завдання настройки мережі. Етап корекції завдань настройки і оперативного управління є частиною адаптивного управління. Вказані вище кроки аналізу, синтезу та управління ІТМ є основою структури методології ризик-адаптованого управління ІТМ СКП, яка включає такі елементи: принципи, моделі, методи, прикладні засоби . Методологія базується на принципах декомпозиції, узгодження цілей та координації управління, потокового аналізу і моделювання процесів, адаптивного та ризик-орієнтованого управління. Визначено склад та особливості моделей (математичних та системних) і методів, які є основою методичного апарату. Прикладна частина методології реалізована інформаційною технологією адаптивного управління розподілом трафіку мережі. На її основі вирішується питання взаємодії технічних і програмних засобів при управлінні розподілом трафіку та організації збору, обробки та передачі інформації в системі управління. Адаптивність управління забезпечується вирішенням завдань настройки мережі. Ризик-орієнтованість відображено двома контурами зворотного зв'язку, в яких передбачається оцінка та управління ризиками на етапах структурно-параметричного синтезу та розподілу трафіка мережі. **Висновки.** Реалізація запропонованої методології для синтезу та управління ІТМ дозволить забезпечити функціонування СКП, адаптивне до зовнішніх умов та стійкого до ризиків, що сприяє підвищенню безпеки системи.

Ключові слова: інформаційно-телекомунікаційна мережа, ризики, адаптивне управління, інформаційна структура, параметри, методологія.

ПРИНЦИПЫ И СТРУКТУРА МЕТОДОЛОГИИ РИСК-АДАПТИВНОГО УПРАВЛЕНИЯ ПАРАМЕТРАМИ ИНФОРМАЦИОННО-ТЕЛЕКОММУНИКАЦИОННЫХ СЕТЕЙ СИСТЕМ КРИТИЧЕСКОГО ПРИМЕНЕНИЯ

Предметом исследования в статье являются процессы структурного синтеза и параметрической анализа информационно-телекоммуникационных сетей (ИТМ). **Цель** – разработка методологического аппарата, применение которого позволит получать структурные и технические параметры ИТМ для обеспечения функционирования систем критического назначения (СКН), адаптивного к внешним условиям и устойчивого к рискам. **Задача:** формулирование принципов и определения

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структуры методологии риск-адаптивного управления параметрами ИТМ СКН; определение состава методичного аппарата и прикладных средств предлагаемой методологии. Используются общенаучные **методы:** системный анализ, структурно-параметрический синтез, методы декомпозиции и агрегации, методы риск-адаптивного управления. Получены следующие **результаты**. Приведена схема основных этапов проведения анализа ИТМ. При этом определены элементы распределенной архитектуры ИТМ СКН. Перечислены требования для расчета характеристик информационной и технические структур сети. Рассмотрены способы закрепления приложений СКН за функциональными узлами сети. Определены шаги, которые выполняются на этапе решения задачи настройки сети. Этап коррекции задач настройки и оперативного управления является частью адаптивного управления. Вышеуказанные шаги анализа, синтеза и управления ИТМ являются основой структуры методологии риск-адаптивного управления ИТМ СКН, которая включает такие элементы: принципы, модели, методы, прикладные средства. Методология базируется на принципах декомпозиции, согласования целей и координации управления, потокового анализа и моделирования процессов, адаптивного и риск-ориентированного управления. Определен состав и особенности моделей (математических и системных) и методов, которые являются основой методического аппарата. Прикладная часть методологии реализована информационной технологией адаптивного управления распределением трафика сети. На её основе решается вопрос взаимодействия технических и программных средств при управлении распределением трафика и организации сбора, обработки и передачи информации в системе управления. Адаптивность управления обеспечивается решением задач настройки сети. Риск-ориентированность отражена двумя контурами обратной связи, в которых предполагается оценка и управление рисками на этапах структурно-параметрического синтеза и распределения трафика сети. **Выводы.** Реализация предложенной методологии для синтеза и управление ИТМ позволит обеспечить функционирование СКН, адаптивной к внешним условиям и устойчивой к рискам, что способствует повышению безопасности системы.

Ключевые слова: информационно-телекоммуникационная сеть, риски, адаптивное управление, информационная структура, параметры, методология.

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