Increasing the Reliability of a Heterogeneous Network using Redundant Means and Determining the Statistical Channel Availability Factor

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Abstract

The purpose of the article is to develop recommendations for controlling the reliability of a communication network by introducing redundant facilities and using statistical data evaluation. Improving the reliability of communications is ensured through the use of redundant facilities that duplicate the most critical objects. The reliability indicator is the load route availability factor, which is represented by predefined sequences of interstation directional channels used to transmit information between two points (nodes) of the network, taking into account the type of load of the telecommunication channel. A reliability assurance scheme has been proposed, which is intended to develop an action plan aimed at preventing hazards or at least reducing their negative consequences. Monitoring of network reliability indicators will allow for conducting its dynamic control, and the use of backup facilities that duplicate the most critical facilities will eliminate possible consequences of danger.

Keywords

Reli-availability, availability factor, communication channel, load route, communication route, between nodes, communication network, monitoring of reliability indicators.

1. Introduction

Before considering reliability issues, it is necessary to recall the structure of a heterogeneous Telecommunication Network (TCN) [1–4]. The scheme of a full-fledged heterogeneous TCN is a three-level hierarchical sequence of multiplexers (Fig. 1).

The first level of multiplexing (compression) uses the separation of transmission channels by frequency, and time:

$$C = \sum_{\nu_1}^{\nu_k} C\{\nu_i\} \sum_{t_1}^{t_l} C\{t_i\} = \sum_{\nu_1}^{\nu_k} \sum_{t_1}^{t_l} C\{\nu_i, t_i\} \quad (1)$$

$$, \nu_i = \overline{\nu_1, \nu_k}, \; t_i = \overline{t_1, t_l}, \; i \geq 1,$$

where ν_i is the number of frequency intervals; t_i is the number of time intervals; i is the number of a channel in order (non-negative integers).

The second level includes signals of different physical nature:

$$C_{II} = \sum_{f(E)_1}^{f(E)_m} C\{f(E)_i\}, \quad (2)$$

$$f(E)_i = \overline{f(E)_1, f(E)_m},$$

where $f(E)_i$ is the number of energy channels.

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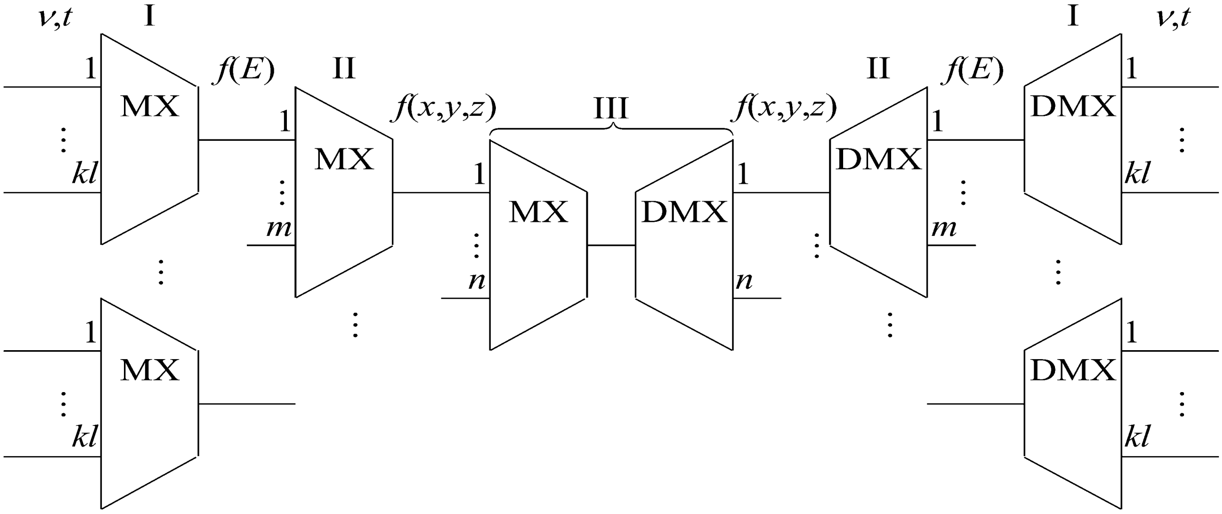

Figure 1: Functional diagram of a heterogeneous TCN: I is the level of channels multiplexing with frequency and time division of signals; II is the level of channels multiplexing with signal division by physical nature; III is the level of channels multiplexing with signal division by transmission medium

2. Research Results

The reliability of the components of a heterogeneous telecommunication network is understood as the ability to maintain over time within the established limits the values of all parameters that characterize the ability to perform the required functions in the specified modes and conditions of use, maintenance, storage, and transportation [5].

The reliability scheme is shown in Fig. 2.

The suggested scheme is designed to develop an action plan aimed to prevent hazards or at least reduce their negative consequences. Short-term hazard forecasting is performed to alert the public and collect data. These data are used in long-term forecasting, which in turn is used to assess risks and their permissible levels to declare the safety of facilities, make decisions on their location and operation, develop measures to prevent accidents, and prepare for response to them. The list of protection measures includes:

- Use of materials and structures resistant to a particular hazard.
- Hazard interception involves shielding the facility or its most vulnerable and critical elements from the hazard, or shielding the hazard from the facility, as well as counteracting the hazard.

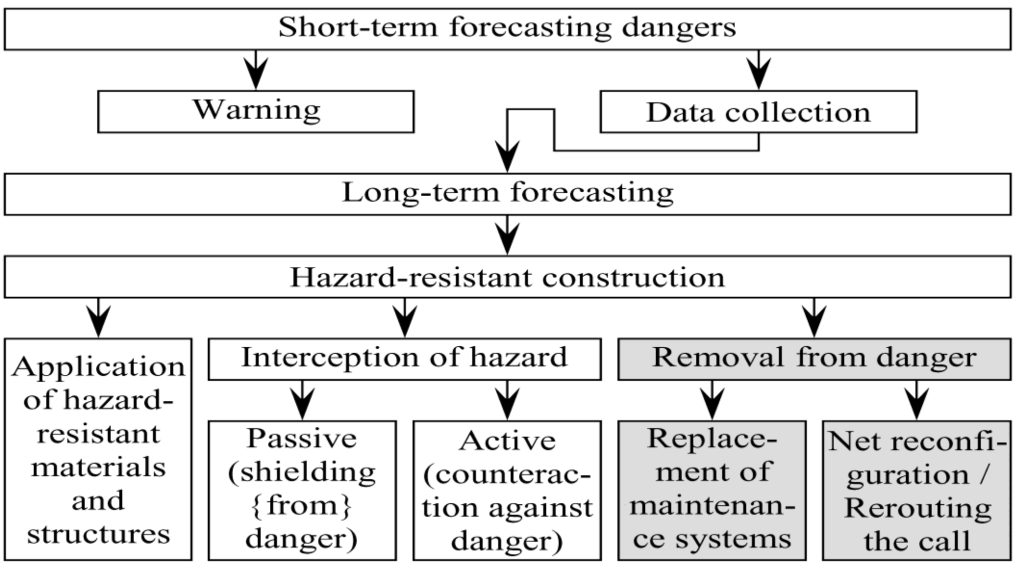

Figure 2: The scheme for ensuring the reliability of the facilities by applying hazard protection measures [6]

- Replacement of maintenance systems (power supply, ventilation, air conditioning, fire alarm, fire extinguishing, warning, etc.).
- Reconfiguration of the communication network by redistributing resources [7, 8].
- Alternative routing (call re-routing), in which traffic includes at least one node not involved in the previously selected route [9].

Reconfiguration/re-routing can be performed by load balancing, in which the task of establishing communication is distributed among several network devices. This is done, in particular, to optimize resource utilization, reduce request service time, and horizontal cluster scaling (dynamic addition/removal of devices) [10–12].

Elimination of hazards is ensured through the use of backup facilities that duplicate the most critical facilities. It should also be noted that the use of monitoring of network reliability indicators is effective, allowing conducting their dynamic control [13–15].

The purpose of the paper is to develop recommendations for controlling the reliability of a communication network by introducing redundant facilities and using statistical data evaluation. Increasing the reliability of communications is ensured through the use of redundant facilities that duplicate the most critical objects.

Reliability is the feature of an object to maintain over time within the established limits the values of all parameters that characterize its ability to perform the required functions in the specified modes and conditions of use, maintenance, storage, and transportation.

Reliability is one of the components of an object's functional stability. Fig. 3 shows that the components of functional sustainability are reliability, survivability, and fault tolerance.

The indicators of the functional sustainability components are considered by the following groups:

1. Reliability indicators.
2. Indicators of survivability.
3. Indicators of fault tolerance.

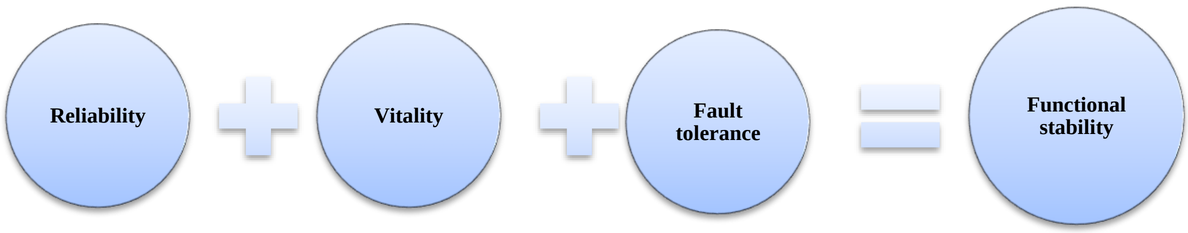

Figure 3: Components of functional sustainability

This paper will focus on the reliability property of an object.

It is indicated that reliability is a complex feature that, depending on the purpose of the object and the conditions of its use, may include reliability, durability, maintainability, and preservation or certain combinations of these properties. It is also indicated that this term is used only for a general non-quantitative description of these properties [5].

One of the parameters for quantifying this reliability is the time between failures [16]. The quantitative indicator of reliability, and availability, use the term "time to failure of the telecommunication channel"—Time to Failure (TTF).

The statistical channel availability factor for a certain period of observation time Δt is calculated by the formula [16–18]:

$$k_{ch}(\Delta t) = \frac{TTF_{ch}}{TTF_{ch} + TTR_{ch}}, \ \Delta t > 0, \tag{4}$$

where $TTF + TTR$ is the considered time interval; TTR is the time-to-repair (time to restore the telecommunication channel performance).

TTR_{ch} can be calculated by the formula [19]:

$$TTR_{ch} = TTR_{01} + TTR_{12} + TTR_{23}, \tag{5}$$

where TTR_{01} is the time interval from the failure to its detection (undetected fault time), for example, in the case of a latent failure; TTR_{12} is the time interval during which maintenance is prepared (maintenance support performance). TTR_{12} is characterized by a certain time interval of logistic delay (including delivery of parts and tools; delivery, installation, or calibration of measuring instruments; the arrival of specialists;

the processing of technical documentation; delivery registration; waiting for transportation; delay due to unacceptable environmental conditions, etc.), including administrative delays (time interval of waiting for logistics resources, which does not include delivery of spare parts); TTR_{23} is an active repair time.

Fig. 4 shows an example of communication channel redundancy.

The route between nodes A and B is made up of load routes, which are predefined sequences of interstation channels and are used to transmit information between two points (nodes) of the network, taking into account the type of telecommunication channel load.

The load can be considered as the process of receiving and withdrawing requests for telecommunication network resources [20].

By the type of load, the unified communication network is divided into technological and corporate (production and economic) networks [21]. The technological segment of the network includes the means of an automated dispatch control system: a complex of remote control and data collection; a subsystem of automatic frequency and power control; a complex of control and optimization of electrical modes; a complex of dispatch simulator; a complex of equipment repair scheduling and coordination procedures. The corporate segment of the network includes organizational and economic management; production and economic management; operational and dispatching and operational and technological management (voice information); repair and maintenance of facilities [22–31].

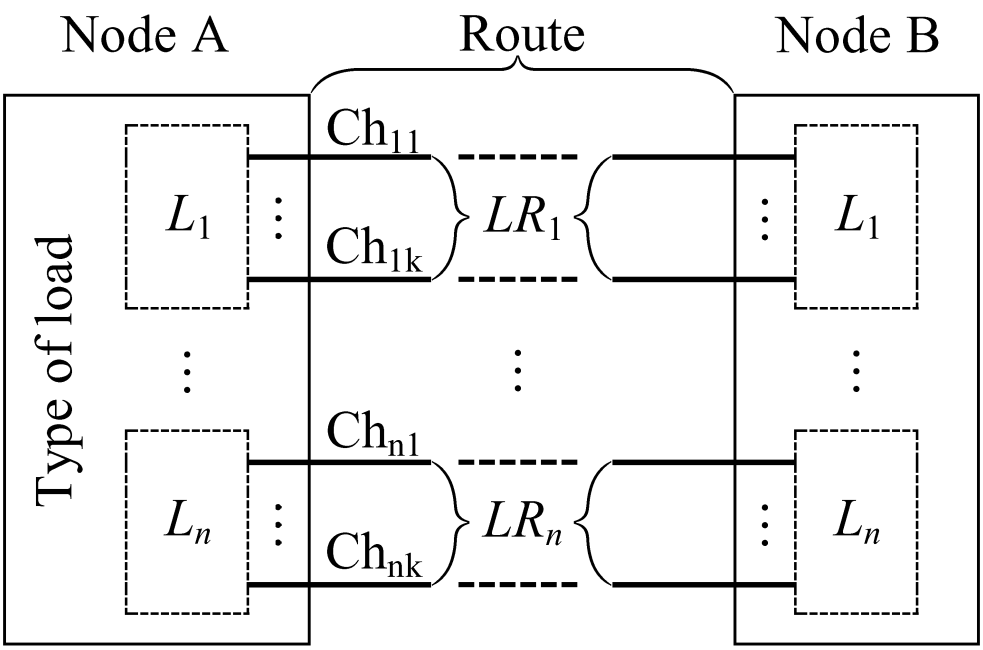

Figure 4: Communication route between nodes A and B

3. Conclusions

When calculating the availability factors of communication channels, load routes, and the communication network, statistical data have been used. By entering the sequence of operations for calculating availability factors and the conditions for monitoring network reliability indicators, dynamic control of the network can be performed.

Increasing the reliability of communications is ensured through the use of redundant facilities that duplicate the most critical facilities. The reliability indicator is the load route availability factor, which is represented by predefined sequences of interstation channels used to transmit information between two points (nodes) of the network, taking into account the type of telecommunication channel load.

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