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Intellectualized computer network control system

The proposed is the conceptual structure of the intellectualized computer network control system based on the expert system and the "optimal administrator" module, the advantage of which is compliance with the general psychophysiological models of the administrator's professional activity, as well as the application of the expert system to determine the optimal control actions and assess the effectiveness of the administrator's management.

Modern computer networks are complex technical systems including tens and hundreds of elements of active network equipment. There is never complete information about the state and parameters of the network. For the effective functioning of such a system, intellectualized control methods are necessary.

Resulting from the research, the concept of an Intellectualized Computer Network Control System (ICNCS) is proposed. The system is built using the reference model, the concept of the "optimal administrator" based on psychophysiological models of the network administrator's professional activity, uses the principles of optimal control and the technology of expert systems.

ICNCS consists of:

- a module for processing the incoming information about the state of the network in the form of a database for storing network operation statistics;
- network status identification module;
- reference information and mathematical model of the network segment with forecasting;
- the "optimal administrator" module for the optimal control formation;
- knowledge bases with a set of rules regarding network control strategies; databases for control efficiency analysis;
- control implementation module.

At the initial stage, ICNCS searches for active network elements of the network, analyzes the parameters and structure of autonomous segments. Based on the obtained results, the state vector of the network segment Y_{asi} (y_{asi}, a, t_0), is being formed, which takes into account the transmission delay and delay variation, the number of lost packets and bit errors.

Data about the state of the network are transferred to the two-level i-y reference model of the network segment M_i, which allows you to separate the task of managing the reliability of the equipment from the task of analyzing and managing the topology of the computer network.

While collecting statistics, the differences between the parameters of the current state vector Y_{asi} (y_{asi}, a, t_0), information about which is received with a delay of the information (k) signal, and the state vector of the reference model y_{Mi} are taken into account.

The identification module based on the vector of the current state of the network and information-entropy criteria allows you to determine compliance with one of four states:

s_1 – operational;

s_2 – overload;

s_3 – temporary (floating) failure;

s_4 – complete failure.

The reference model, describing the processes of information exchange in a network segment, is based on differential and difference equations with deviating arguments, which allow taking into account the delays of both signaling (k) and control (m) information. The stability of the state of the autonomous segment during signal delays is ensured thanks to the developed stability control method.

Based on the method of analysis of statistical characteristics and models of demand flows, a vector of output signals of the first level of the reference model is formed, which makes it possible to obtain a forecast regarding the state of the elements and the traffic intensity at the control points of the network.

On the basis of the vector of output signals of the second level of the reference model, a vector of network serviceability forecast $Y_{as_i}(y_{as_i}, a, t_k, t)$ for future periods is formed. The "optimal administrator" module uses the developed method of optimal control to bring the segment to the desired state t_k with minimal expenditure of control resources. Here, the nominal values of the quality target indicators *QoS* (and some other) parameters are entered as components (scalar functions) into the vector of optimal controls u_{opt}, after which the optimization problem of finding the global extremum is solved once

$$u_{\text{opt}_i} = \min_{y,\theta} I_{\text{г}}\left[Y_{as_i}(y_{as_i}, a, t_k, t), t\right].$$

In the process of further network functioning, the extreme is monitored and "adjusted" to it in the event of deviations in the parameters of the control system a.

In parallel with an administrator with standard qualifications and work experience, the same tasks are solved by an expert system that is optimal in the sense of minimizing the given target functions, the "optimal administrator". This system, like the administrator, receives information about the state of the network and the forecast of performance. By minimizing the target function, the optimal control is being produced, on the basis of which, with the help of a knowledge base, a control strategy is being formed. The knowledge base should contain a set of rules for optimal control strategies

$$\left\{Y_{as_i}, u_{\text{opt}_i}, Y_{as_i}^{S_1}, Y_{as_i}^{S_2}\right\} \Rightarrow \left\{U_{\text{opt}ij}^{\;p}\right\},$$

which must be accepted in the current situation. The knowledge base is built according to the production model and contains information about optimal network control strategies according to the desired state of the segment and the minimum of control actions. The Working Memory Module contains information about the current state of the system and the decisions made. The Solution Explanation Tool provides the network administrator with a list of rules used in the process of logical derivation of the optimal control strategy, which allows increasing confidence in the result achieved. The logical derivation engine is based on declarative programming languages. Experts filling the knowledge base can act as: specialists of network equipment manufacturers; experienced administrators or a group of network administrators; users are customers of services. The solutions produced by the expert system are considered as benchmarks and are provided to the operator, providing intelligent decision support and automated learning.

On the basis of information about the current and projected state of the Network, recommendations on optimal control actions, the Administrator forms a control strategy and implements it with the help of the module of the control actions implementation in the form of commands of the corresponding protocols $\{U_{pij}\}$.

To analyze the efficiency of management, the optimal control (produced by an expert system), administrator's control actions, and network states are recorded in the database. The control effectiveness is assessed by the impact on the network performance. Current efficiency ratio

$$R_{eff} = \Psi_1(t) / \Psi_2(t),$$

determines the ratio Ψ_1 – of network efficiency with control to Ψ_2 – network efficiency without control.

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