УДК 004.942:004.62

MATHEMATICAL MODEL OF A MULTILAYER INFORMATION SYSTEM FOR STREAM DATA PROCESSING

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This work considers multilayer information systems for stream data processing in the context of integration with other system classes. A mathematical model is proposed. It considers the multilayer structure of the information system, the dynamic nature of data streams, and physical resource constraints. The model can be adapted to optimize computing resources in high-availability systems and to create heterogeneous computing environments within a unified information system.

Modern information systems are characterized by synergy with other system classes, including large-scale data registration systems, cyber-physical systems, and others. The integration of such systems presents challenges related to the creation of multilayer structures. This is due to the requirements for decomposing of computing processes to ensure their isolation from similar processes within a unified computing environment while considering the degree of isolation of each computational cell [1]. Thus, classical information systems are becoming increasingly rare in practical applications, while hybrid systems are more prevalent. One of the key factors driving this shift is the rapid development of artificial intelligence and machine learning. The nature of the data being processed, stored, or transmitted within such systems, as well as in conjunction with other (external) systems within the framework of megasystem paradigms, also introduces specific challenges. Streaming data is considered the most complex type of data due to the dynamic intensity of data flows, density, and the requirements for quality, priority in transmission, processing, or reliability in storage [2]. Mathematical models describing such system subclasses are generally impractical and extremely difficult to optimize.

This paper examines one such example of integration, focusing on the development of a system for registering and distributed processing of data streams, followed by the synthesis of these results to prepare for further analysis and the identification of predefined features (or characteristics) by the system's subsystems at each of its levels. This approach represents a specific abstract model of computational process organization. Accordingly, the study aims to generalize this subclass of systems and develop a standard mathematical model for a multilayer information system for stream data processing.

Let the information system N consist of η-layers (levels). Each layer of the information system can be described as a tuple:

$$\eta_i = \langle \gamma_j, \lambda_m, \varsigma_k \rangle,$$

where γ_j – computing structures (where $j = A$, if the structure is represented by a virtual machine; $j = B$, if the structure is represented by a container.); λ_m – a switching node that ensures data transmission within the layer; ς_k – a boundary node of the layer.

Thus, a typical mathematical model of a multilayer information system for stream data processing can be represented as follows:

$$\mathrm{N} = \bigcup_{i=1}^{\eta} \langle \gamma_j(i), \lambda_m(i), \varsigma_k(i), D_i(t) \rangle, \ \eta \le \eta_{\max}$$

where $\gamma_j(i)$ – computing structures of the i-layer; $\lambda_m(i)$ – a switching node of the *i*-layer; $\varsigma_k(i)$ – a boundary node of the i-layer; $D_i(t)$ – the temporal dynamic data flow of the i-layer; $\eta_{\max}$ – the maximum number of layers limited by the resources of the physical system.

The proposed mathematical model can account for additional conditions, including bandwidth limitations, multi-system architecture at the upper level, migration of computational structures between levels, and others.

Further research on this topic involves the development of adapted models for specific systems or their classes aimed at creating sets of behavioral rules in high-availability intelligent systems, where there is a need to restructure the architecture of the information system depending on the dynamics of the tasks it is solving.

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