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Research Article

EFFICIENCY EVALUATION OF IN-HOUSE SOFTWARE FOR CONTROL COMPUTING FACILITIES OF DATA TRANSMISSION SYSTEMS

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ABSTRACT

The article discusses the justification and selection of criteria for evaluating the effectiveness of software used in control computing facilities (CCF) for data transmission systems (DTS). It focuses on two main types of CCS with a multi-step program execution pattern and a limited number of load sources. The effectiveness of in-house software by using statistical modeling of CCF functioning is also evaluated in the article. It proposes a methodology for assessing the in-house software's effectiveness for CCF of DTS, which would help determine how well the developed software meets the basic requirements for CCF functioning.

KEYWORDS

Criterion, efficiency, in-house software, functionality, methodology, statistical modeling.

INTRODUCTION

One of the important tasks that arises at the stages of system and system-technical design of a DTS communication network is assessing the effectiveness of the CCF of DTS software. It is necessary to evaluate the effectiveness of that part of the software that directly affects the time characteristics of the functioning of control computing facilities and the efficiency of the data transmission system as a whole. This part of the in-house software is a complex of programs that implement the functions assigned to the control computing facilities. The in-house software includes a complex of programs for functional tasks, functional control, and an operating system (dispatcher programs).

MAIN PART

To evaluate the effectiveness of the in-house software of the CCF of DTS, a criterion must be selected that would allow establishing the degree of compliance of the developed or being developed software with the basic requirements for the functioning of the CCF. As follows from the considered features of the operation of the CCF of DTS /1,2,3,4/, compliance of the software with the requirements to the CCF functioning is understood not as ensuring fulfillment of the specified functions (which is considered to be unconditionally fulfilled), but as ensuring servicing of the requirements with delays not exceeding the specified or maximum permissible ones.

The choice of criterion depends on the type of CCF and the mathematical model /5,6/ of its functioning. If all requests for service are equivalent, then the following criterion can be used: the probability that not all requests received for service will be serviced untimely must not exceed a certain acceptable value of S:

$$Э = P\left\{T_j > t^j_{\max}\right\} \leq S. \qquad (1)$$

The given criterion reflects the most essential requirement for the functioning of the CCF determined by the presence of strict restrictions on the magnitude of delays in program execution. It is appropriate that the software ensures the functioning of the CCF with minimal costs for executing programs (Y_z) :

$$Z = \min Y_z \qquad (2)$$

Considering the mathematical models of the CCF functioning, discussed in /7, 8/, the criterion for the effectiveness of the in-house software of the CCF with the multi-step pattern of program execution can be the following functional:

$$Э = \sum_{i=1}^{k} \bar{t}_{oi} \sum_{j \in m_i} \lambda^i. \qquad (3)$$

If the following conditions are met:

$$\left.\begin{array}{l} \bar{t}_{oi} < t_{i\max} \\ \bar{\tau}_i \leq \tau_{i\max} \\ \bar{T}_j \leq t_{j\max} \end{array}\right\} \qquad (4)$$

at general loading of the CCF of the node with programs of functional tasks and functional control:

$$\rho = \sum_{i=1}^{k} (t_i + \bar{t}^*_j) \sum_{j \in m_i} \lambda^j < 1$$

Based on the above, it is proposed to use the average delay in the start of execution of all subroutines as a criterion for the effectiveness of the in-house software of the CCF of DTS with the multi-step pattern of program execution, while the system must be in a stationary mode $(\rho < 1)$ and the requirements for the operability of the CCF (conditions 4) must be met.

The use of criterion (3) with conditions (4) can serve to assess the efficiency of the operating system, clarify the distribution of programs and subroutines by priority levels, and select a dispatching algorithm (computer time distribution).

A criterion for the effectiveness of the in-house software of the CCF with a limited number of load sources can be the following functional:

$$Э = \bar{T}_0 \sum_{i=1}^{n} v_i \qquad (5)$$

if the following conditions are met:

$$\left.\begin{array}{l} \bar{T}_0 < T_0 \max \\ \bar{T} \leq T \max \end{array}\right\}, \qquad (6)$$

where $T_0 \max$ - is the maximum allowable request waiting time;

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$T\max$ - is the maximum allowable request processing time.

Thus, it is proposed to use the average total request waiting time as a criterion for the effectiveness of the in-house software of the CCF of DTS with a limited number of load sources, while the requirements related to the performance of the CCF - load concentrators (conditions 6) must be met.

The suggested criteria (3) and (5), along with their corresponding conditions (4) and (6), have clear physical interpretations and consider the key characteristics of the operation of DTS computing facilities. These criteria are advantageous due to their relative simplicity: when the values of the quantities involved are known, the calculations using formulas (3) and (5) are quite straightforward.

If there is no analytical queuing model for a given CCF, it is necessary to use the method of statistical modeling of the CCF functioning on general-purpose digital computers (DCs) /9/. To solve the problem of analyzing the CCF of DTS as a queuing system (QS) using the method of modeling of the CCF, all the basic techniques that are general for studying other classes of queuing systems are applicable. At the same time, a method that requires the creation of a generalized model of the CCF as a queuing system is preferable to a method based on the use of a model of the command system of the CCF. The first of these methods is associated with significantly less computer time; in addition, to assess the time characteristics of the CCF and the effectiveness of its in-house software, the accuracy of the results achieved when using the second method is not necessary.

When using the method that requires the creation of a generalized model of the functioning of the CCF, the information processing is not reproduced in it, but only the principles of the timing parameters of programs and subroutines are considered. In this case, the time intervals occupied by the execution of each subroutine are simulated. A program capable of reproducing the functioning of the CCF must include blocks that reproduce the operation of the dispatching algorithms discussed above, blocks that generate input flows of requests at individual service phases, and blocks designed to obtain statistical characteristics of the CCF functioning.

If the operating durations of subroutines and CCF programs are not constant, then the modeling program must also contain blocks that form service durations in individual phases as random variables with the necessary distribution laws. It should be noted that for the modeling method under consideration, the processing of information by various programs and subroutines is not significant; only the operating time of the corresponding programs (subroutines) is important. The latter is specified as part of the initial data for modeling as a constant value or as an exponential function with parameter (for the CCF with a limited number of load sources).

The simulation can be performed in three steps. In the first step, the functioning of the in-house software is simulated separately for each dispatching algorithm. As a result of the modeling, the statistical characteristics of the process of executing programs in the CCF should be determined (distribution functions for the waiting time of requests in the queue, functions of the stay of requests in each phase and the system as a whole, as well as their central moments). Using the simulation results, a dispatch algorithm is selected that ensures that conditions (4) or (6) are met.

In the second step, the distribution of subroutines by priority levels is clarified and modeling is performed for several options for the distribution of subroutines by

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priority. At the same time, the possibility of combining several subroutines into one priority level and rearranging individual subroutines is considered. A distribution option is selected that has obvious advantages from the point of view of the physical nature of the tasks being performed and, at the same time, allows us to ensure that conditions (4) and (6) are met.

In the third step, the statistical characteristics of the functioning of the CCF are finally clarified with the selected dispatching algorithm and the refined distribution of programs and subroutines by priority levels. If conditions (4) and (6) are met with a reserve, then at this step, the possibility of increasing the number of functional tasks for a given intensity of requests or increasing the intensity of flow for a given volume of functional tasks is considered. The effectiveness of in-house software is assessed according to criteria (3) or (5).

As an example, Fig. 1 shows the block diagram of the algorithm for simulating the functioning of the CCF of the data transmission system, presented in the form of a phase-based QS with a queue at each phase, with a constant service time at each phase and with two incoming Poisson flows of requests. The modeling algorithm is compiled by principles known in the field of statistical research of complex systems and therefore is not explained here.

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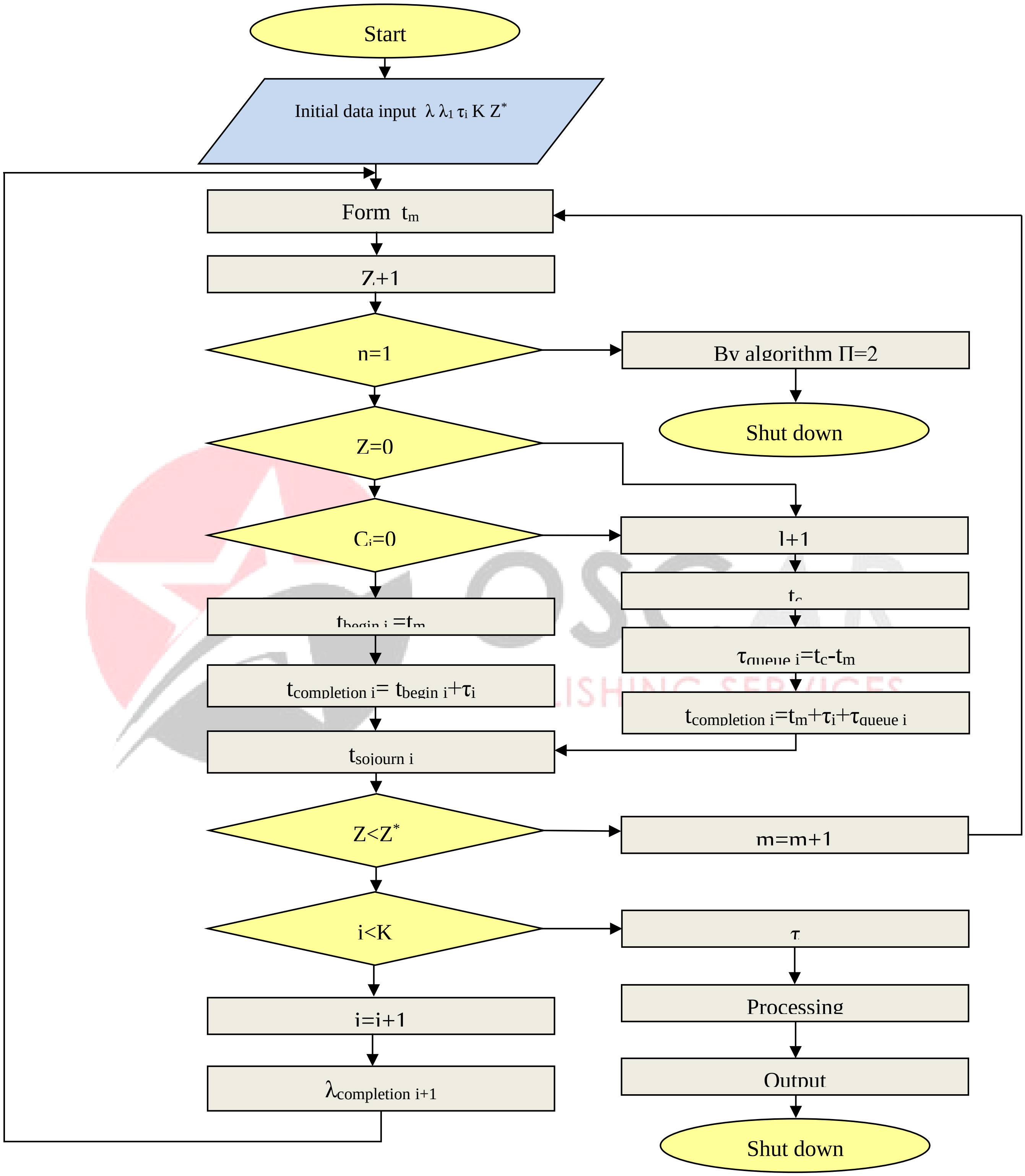

Fig.1. Block diagram of the simulation algorithm

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The following notations are used in the diagram in Fig. 1:

λ - intensity of the total flow of requests;

λ_1 - intensity of the priority flow of requests (service with relative priority);

K - number of QS phases;

t_i - duration of service in the i-th phase;

Z^* - required number of implementations;

t_m - the moment the request enters for service at the next phase;

Z - number of the current implementation;

n - number of the incoming stream (n=1,2);

Z - queue length during the service phase;

C_i - number of the service device in the i-th phase;

$t_{begin\ i}$ - begin time of service in the i-th phase;

$\tau_{sojourn\ i}$ - the time of request sojourn in the i-th phase;

$t_{queue\ i}$ - queue time for a request before the i-th phase;

t_c - takedown time from servicing the previous request;

$t_{completion\ i}$ - completion time of service in the i-th phase;

Using the algorithm shown in Fig. 1, modeling of the functioning of the CCF was conducted with several sets of initial data λ, λ_1, t_i, k. As a result, histograms of the waiting time of requests of two flows and the total flow in the queue before each phase, the time the requests remain in the same flows at each service phase, and the average values, variances, and coefficients of variation of these values were obtained.

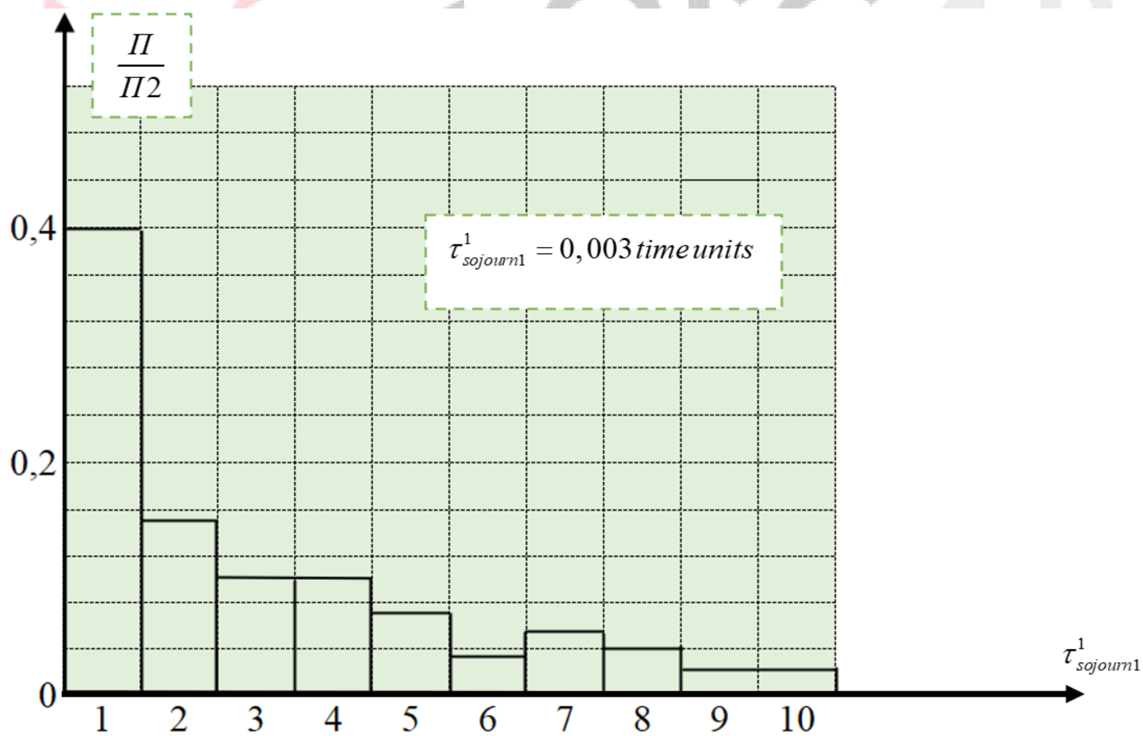

Fig. 2. Histogram of the time the priority flow remains in the first phase

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The results obtained made it possible to evaluate the functioning of the CCF. The assessment showed that

$t_{oi} \leq t_i \max$. In Fig. 2, as an example, a histogram of the time the priority flow remains in the first service phase is shown.

Thus, the following methodology is proposed for assessing the effectiveness of the in-house software of the CCF of DTS, which includes the following steps:

1. Determination of the characteristics of request flows entering the processor (subsystem) of the CCF.

2. Selection and justification of the mathematical model of the functioning of the CCF.

3. Solving the problem of analyzing a queuing system that interprets the functioning of the CCF under consideration. In this step, the duration of execution of programs and subroutines (3) and (5) of values $t_{\text{queue } i}$ and $\overline{T}_0$ are estimated.

4. Checking the fulfillment of conditions (4) and (6). If these conditions are met, then go to step 5. If the conditions are not met, then the developed software of the CCF must be reprocessed. The latter may consist of reprogramming individual parts of the software to reduce the duration of their execution or the use of dispatching algorithms that ensure a reduction in the average delay times of subroutines. After processing is completed, the fulfillment of conditions (4) or (6) is checked again.

5. Calculations using formulas (3) or (5).

Note that it makes sense to evaluate the effectiveness of the in-house software of the CCF only if there are several software implementations that differ at least slightly from each other. However, in any case, when developing software, it is necessary to check the fulfillment of conditions (4) and (6).

CONCLUSIONS

Thus:

- the selection and justification of the criteria for the effectiveness of the software for the CCF of DTS was made for two main types of CCF - with a multi-step pattern of program execution and a limited number of load sources;

- using the method of statistical modeling of the CCF functioning, the effectiveness of the in-house software was assessed;

- a methodology was developed for assessing the effectiveness of the in-house software of the CCF of DTS, the use of which makes it possible to establish the degree of compliance of the developed or being developed software with the basic requirements for the CCF functioning.

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