The simulation model of the system with aggregated channels and redundant transmissions on the multiple access level

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Abstract. The study to improve the probability of timely and error-free redundant transmission of packet copies through aggregated channels, taking into account the influence of the distributed queues organization and their dispatching based on the multiple access procedure is conducted. The simulation model of the data transmission system with aggregated channels and distributed queue with a marker access method is built. The boundaries of the effectiveness of redundant services are determined taking into account delays in the implementation of multiple access to redundant channels.

Keywords: Network, reliability, time-critical delivery, redundant transmission, packets, multiple access

1 Introduction

High structural reliability [1–3], performance [4] and security [5] of data transmission systems and distributed data processing systems are achievable as a result of the consolidation of redundant system resources [6], including communication channels [7, 8]. The improvement of information and communication systems reliability requires the redundancy of both their structure, data processing and transmission processes, especially when the iteration after a failed service is limited to real-time work [9]. The choice of decisions design on the organization of interconnection of nodes in distributed redundant computing systems should be based on modeling [10–12] and structural-parametric optimization taking into account the processes of transmission, storage and processing of data as well as their health and safety monitoring [13].

The study of the possibility of the average waiting time reducing in computer implementations represented by multichannel queuing systems (QMS) as a result of the requests replication with their independent execution by all or part of unoccupied service channels was carried out in [14]. It should be noted, that this solution might result the waiting time increase of received requests when all service channels are busy. For the systems of time-critical requests, it is shown in [15] that backing up copies of all requests in computer systems represented by the set of single-channel QMS (for example, cluster systems) allows, under certain conditions, to increase the probability of timely requests service. Moreover, the effect of the requests timely service probability increase up to a certain limit of increasing their intensity is observed even with the absolute reliability of the system and increases with possible failures, equipment failures and errors in performing the required functions.

The study of the interaction of computer nodes organization through redundant channels was considered in [6, 16, 17].

The object of the study is the system in which interaction between m computer nodes is performed through n aggregated channels (Figure 1).

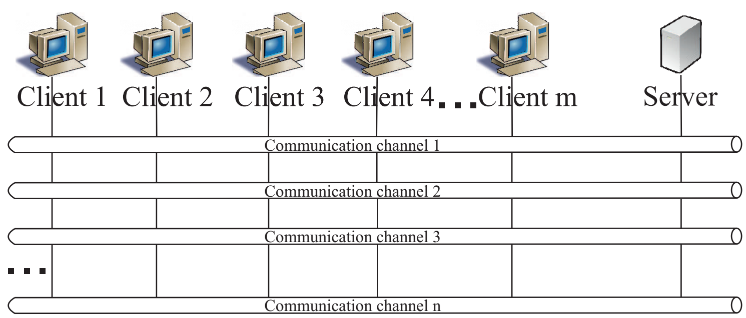

Fig. 1. The scheme of the data transmission system with redundant channels

The feature of the systems under investigation organization is the presence of the queue, which is distributed across system nodes. The organization of this queue depends on the implementation of the interaction of nodes through redundant channels, including their redundant interaction.

We distinguish two limiting options for organizing distributed over nodes queues.

In option A, separate queues are organized at each node to access each of the m channels. Each request is placed in one of the queues with non-redundant service (for example, cyclically or in the least loaded queue). In case of redundant service with multiplicity k, k copies are created, each of which is entered into one of the n queues. When connecting computer nodes to channels (backbones) via network adapters, queues can be organized both in the computer node and in network adapters.

In the variant of queuing A, the n-channel data transmission system can be represented as a set of n single-channel QMS [14, 15], each of which has a common queue distributed across the nodes of the system.

With option B, a common queue at each computer node is organized to access all n channels. In case of non-redundant service after release (obtaining access privileges) of one of the n channels, a request at the beginning (output) of the queue is transmitted via it. In case of redundant service, a request that is at the head of the queue creates k copies, each of which is sent as it is released (granted access) to the k channels. When a computer node is connected (in which a queue common for all channels is organized) to n channels via n network adapters, k copies of the request from the top of the queue are put into k from the n adapter. With this queuing system, the data transmission system through the reserved channel is represented by multi-channel QMS with a common distributed queue.

The estimates of the average latency and timeliness of redundant servicing of the requests for packet transmission through redundant channels when presented by a combination of single-channel QMS can be based on the analytical models proposed in [16–18].

The effectiveness of the backup service requests for the transfer of packages through aggregated channels, when presenting the analyzed system as a multi-channel QMS with a common queue, was studied in [19] on the basis of a simulation model, which, however, does not take into account the costs of dispatching the distributed queue services hosted in various nodes of the system, implemented by means of a multiple access procedure.

The most common is the random method of multiple access, but it does not provide guaranteed access time (calculated for the worst case), which makes it difficult to use it in real-time computer systems (including managing systems). For real-time systems, it is advisable to use deterministic multiple access methods, including the token [20] method. The advantage of the marker method for real-time systems is the ability to:

- ensuring guaranteed access time,
- setting and reprogramming the logical ring of the transfer of access rights,
- specifying the number of transmitted packets when obtaining access rights,
- priority service requests.

Figure 2 shows the chart of the organization of a distributed queue using the token access method. Each channel has the token transmitted in accordance with a given logical ring of its transmission. The logical ring of the token transfer is organized for each of the n channels. If there is the request (packet) in the node's queue stored in the network adapter, then the adapter starts its transmission after token receiving. After the node completes (via the network adapter) the required transfers, the token is transmitted to the network adapter of the next node in the logical ring. If there are no packets to be sent in the adapter, then it is transmitted to the next node in the logical ring after token receiving. In the case of redundant transmissions when the common queue is organized in a computer node, from its beginning, k copies of the request are recorded in k of n network adapters, each packet is transmitted independently when the adapter receives a token included in the logical ring of the corresponding channel token. Due to the non-synchronous transmission of different channels tokens, the time difference between the delivery of packets from one node through different channels is possible.

The aim of the work is to study the possibilities of increasing the probability of timely and error-free redundant transmissions of the packet copies through aggregated channels, taking into account the influence of the distributed queues

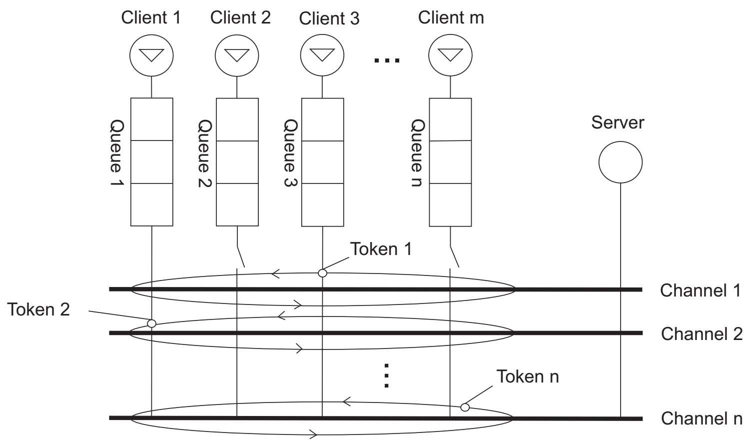

Fig. 2. The scheme of the distributed queue organization with token access method

organization and their dispatching based on the multiple access procedure. The effectiveness of the packet copies redundant transfers through aggregated channels is analyzed when presenting the system based on multi-channel QMS with a common queue distributed between the nodes.

The aim of the study is to resolve technical contradictions associated with the fact that redundant service: increases the likelihood of error-free packet delivery, but on the other hand leads to the load increase, which leads to the increase in the transmission time of packets through separate channels and, accordingly, reduce the probability of timely delivery.

As an indicator of efficiency, we use the multiplicative criterion of the form $M = P(t_0 - T)$ [19], which reflects the timeliness and accuracy of packet delivery, where P is the probability of error-free packet delivery, T is the packet residence time in the system, t_0 is the maximum allowable delivery time.

The results of the study were obtained on the basis of the simulation model implemented in the AnyLogic 7 environment.

2 Building the Simulation Model

Figure 3 shows the simulation model of the data transmission system with redundant channels and the distributed queue organization based on the multiple access token method.

In this model, the *sourcei* blocks are the sources of i-th subscriber packets. Blocks *spliti* - create the required number of copies. The *queuei* blocks are endless queues of i-th subscriber packets. The *holdi* and *delayWi* blocks are responsible for the transfer of the token. The *selectOutputIn* and *selectOutoutOuti* blocks are the technical blocks responsible for the distribution of packets over communication channels. Blocks *delayi* - 8 identical communication channels.

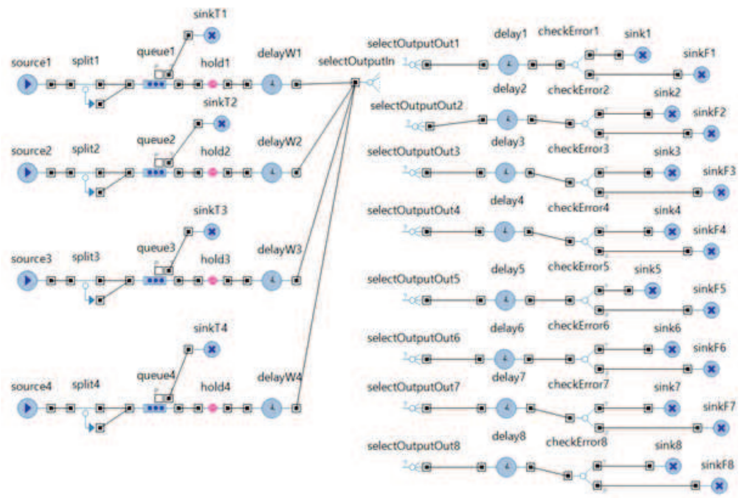

Fig. 3. The simulation model of the data transmission system with the distributed queue organization based on the multiple access token method

CheckErrori blocks - checks the package error-free delivery. *Sinki* blocks are responsible for keeping track of correctly delivered packages. The *sinkFi* blocks are responsible for keeping track of packets delivered with an error. *SinkTi* blocks - are responsible for the packets accounting lost due to exceeding the maximum allowable time.

3 Simulation Results

The simulation experiments were carried out with varying the total intensity of input streams with values $\lambda = 1$ ... 10000 1/s; $m = 8$ is the number of channels in the service system; $L = 1$ Mbit/s - the capacity of each of the communication channels; the probability of bit error in the channel $B = 10^{-5}$; $N = 1024$ bits - the average length of packets arriving in the system; maximum delivery time is $t_0 = 0{,}0002$ s for the cases of redundant and non-redundant services.

Figures 4 and 5 show the dependencies of the service efficiency (timeliness and accuracy) estimated by the complex indicator M, without taking into account the costs of the multiple access procedure and taking them into account when using the marker access method, respectively. Transmission without reservation corresponds to curve 1 and with redundancy of multiplicity 2 - curve 2.

From the presented charts one can see the existence of the expediency of applying redundant services region at low values of the input request flow intensity. In this case, the multiple access procedure to communication channels loss leads to the reduction in the area of redundant services use expediency.

It is interesting to compare the simulation results without taking into account access to communication channels and with the token access method at different

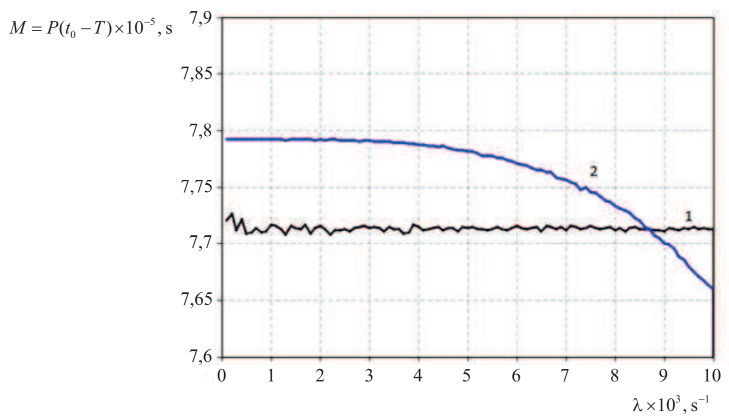

Fig. 4. The efficiency of service without taking into account the costs of the multiple access procedure

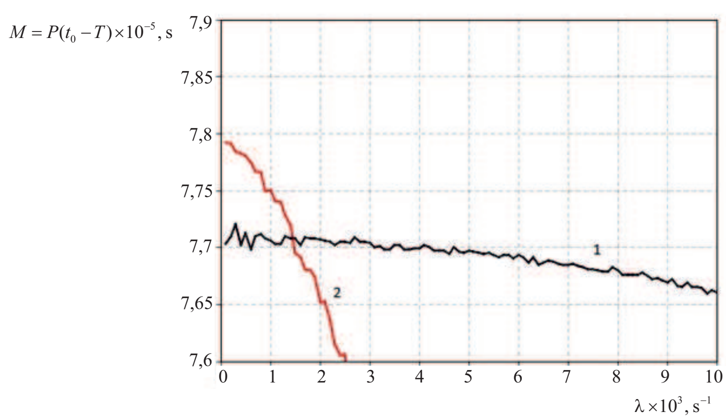

Fig. 5. The efficiency of service taking into account the costs of the multiple access token method

redundancy rates. Figures 6 and 7 show the charts of the efficiency in terms of M without redundancy and with redundancy ratio 2 respectively. Curves 1 and 2 correspond to the redundant transmissions effectiveness in the case of taking into account and not taking into account losses of the token access method implementation. The difference of efficiency with and without accounting the token access method implementation losses is represented by curve 3.

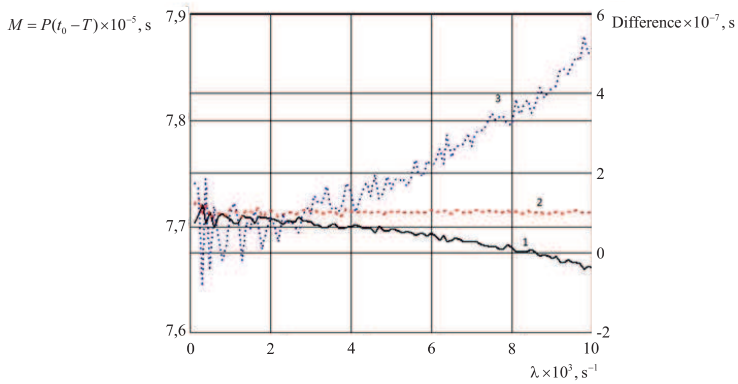

Fig. 6. The efficiency of service with non-redundant transmissions with and without the multiple access token method

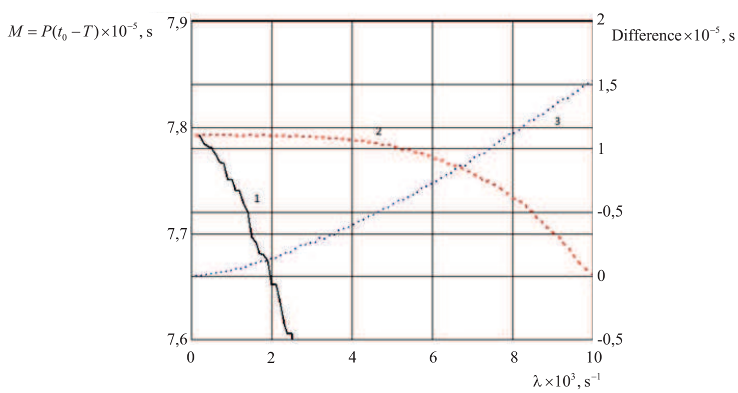

Fig. 7. The efficiency of service with redundancy ratio 2 with and without the multiple access token method

The presented charts show the decrease in the efficiency of service when accounting the costs of providing access to communication channels.

4 Conclusion

The simulation model of the data transmission system through aggregated channels with the token method of multiple access is built. The boundaries of the expediency of the use of redundant service, taking into account multiple access to redundant channels are identified. The impact on the effectiveness of redundant dispatching transmissions of queues distributed between computer nodes based on multiple access is evaluated.

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