IOP Conf. Series: Materials Science and Engineering **450** (2018) 052018 doi:10.1088/1757-899X/450/5/052018

Simulation modelling of the heterogeneous distributed information processing systems

G A Ontuzheva[1,2], E R Bruchanova[1], I N Rudov[1], N O Pikov[1] and O A Antamoshkin[1,2,3]

[1] Department of Information Technologies in Creative and Cultural Industries, Siberian Federal University, Krasnoyarsk, 79, Svobodny Ave., Krasnoyarsk, 660041, Russia
[2] Reshetnev University, 31, Krasnoyarsky Rabochy Ave., Krasnoyarsk, 660037, Russia
[3] Krasnoyarsk State Agrarian University, 90, Mira Ave., Krasnoyarsk, 660049, Russia

E-mail: galya679@mail.ru

Abstract. This study reviews simulation modelling of the heterogeneous distributed information processing systems. The relevance of simulation modelling for the considered class of systems is substantiated. The purpose of the study is outlined and solutions of the tasks required for its achievement are described. Based on the structural modelling carried-out earlier, main types of the model elements and the relations between them are allocated. The network structure generation algorithm is presented. The behaviour and the structure of model elements are described. Results of the modelling are displayed. At the conclusion, the possibilities for further development of the model are considered, and the conclusion on its practical application for real systems is made.

1. Introduction

Heterogeneous distributed information processing systems (HDIPS) are too complex for the analysis and implementation of tests in the actual practice, therefore analysis thereof cannot be done without modeling. The HDIPS may be considered as an extended case of the grid-systems as the HDIPS, same as the grid, may include a set of distributed components, and the grid from homogeneous elements may be a part of the heterogeneous computing system. Application of simulation models in this case is especially relevant as it allows to consider a behavior of the system in different time intervals [1].

The purpose of this study is simulation modeling of the heterogeneous distributed information processing systems.

The basic modeled process is a lifecycle of computing tasks from the computing request to the delivery of computation results of to the decision-maker.

2. Elements and structure of the model

In structural respect the simulation model represents a network made of the elements of several types connected with the communication channels and communicating with the help of messages. In this model the messages are represented with both the TCP/IP packages and the intra model messages imitating different events. Elements of the model correspond to the HDIPS functional elements at the

IOP Conf. Series: Materials Science and Engineering **450** (2018) 052018 doi:10.1088/1757-899X/450/5/052018

applied level and the earlier developed structural model [2-6]. In the HDIPS simulation model, elements of several types are used:

Requestors which imitate occurrence of an event which requires the computation and delivery of information to the decision-maker, they correspond to the sources of primary data in the structural model.

1. Reactive agents of the data sources obtain a signal from the requestors and create a computation request and depending on the type of request determine the necessary software and type of computations.
2. Route management program units determine the sequence of accomplishment of the tasks and integrate the structural model route management agents. In the blocks of this type different route optimization algorithms may be implemented, and the simulation model may be used for comparison of their efficiency in different structures of the network.
3. Blocks storing the statistical information on utilization of the HDIPS elements - nonintellectual elements representing a database of utilization of the computational nodes of the HDIPS. The information to be stored is provided by the route management program units which interrogate the units of its subnet with the frequency set with the parameters of the system.
4. Computational nodes represent the models of the computing equipment agents which trace utilization of the computational node, launch computations of the received computing tasks and forward the tasks further along the route.
5. Decision-maker's program units - passive program units obtaining the information on the solution of the task. The task reported to the required decision-maker is considered fulfilled.

The HDIPS structure in the model is formed in a random way according to the set parameters under the following rules. Each requestor is connected to one reactive agent, the communication channel type (GSM or Ethernet) is determined in a random way [7]. Each reactive agent is connected to a randomly chosen route management pro-gram unit. The route management program units fulfill the role of switches as it is supposed that they are located in the switching equipment of the simulated network [8,9].

Randomly chosen program units of computational nodes, network utilization databases, decision-maker and reactive agents of the data sources are connected to each management program unit. The management program units are also connected among themselves in a random way. In the reviewed model configuration, the delay of communication channels is determined under the normal distribution, and the choice which blocks are connected among themselves - under the uniform distribution, but the model allows to use other types of distributions as well [10,11].

The quantity of elements of different types is set by the user of the of HDIPS simulation model. Figure 1 displays the generated structure of the network consisting of 10 task generators (No. 1) and their reactive agents (No. 2), 10 managing agents (No. 3), 20 computational nodes (No. 5), 1 utilization database (No. 4) and 1 decision-maker (No. 6).

Computational nodes of the HDIPS simulation model have a number of adjustable parameters. The parameters describing a unit of one type are integrated in the computational node profiles, they may be set for each unit, or the profile will be given to the computational node in a random way. The computational node profile includes the following parameters: full space of random access memory, space of random access memory occupied at the modeling launch time, processor utilization at the modeling launch time, hard drive space, empty space on the hard drive at the modeling launch time, list of installed software.

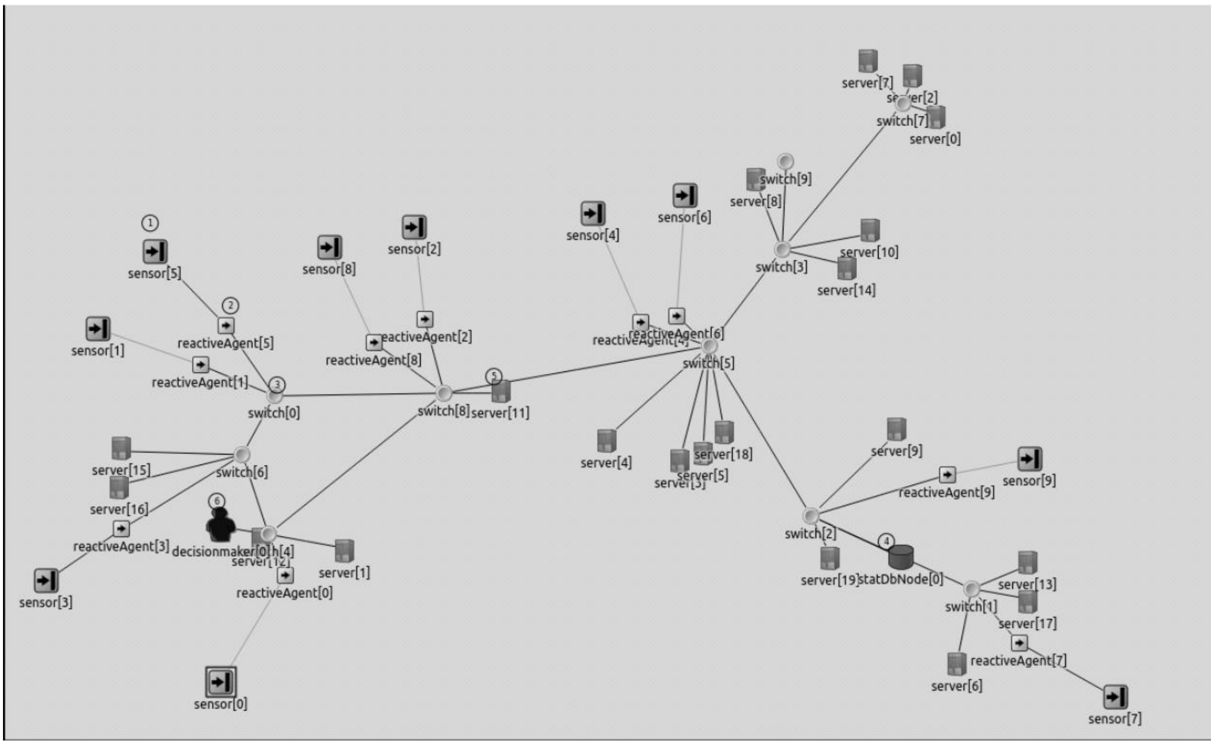

Figure 1. Generated network structure.

For the computing tasks, similar task profiles including the space of random access memory required for the computation, processor utilization with the task, required space of the hard drive and the software, required for the computations, are created. Type of the task which has to be carried out at receipt of a signal from data source is set at formation of the simulation model in the reactive agent in a random way. At receipt of a signal from the source the reactive agent creates the task request including the corresponding task profile and sends it to the managing program unit which determines the optimum route of computations.

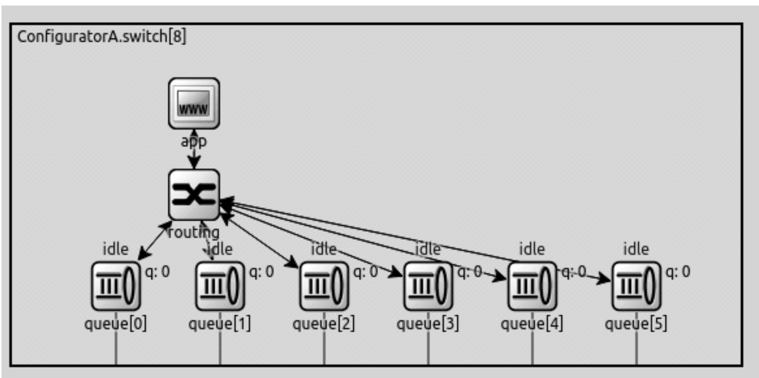

Figure 2. Internal structure of the complex program units.

The App program subunit executes an application of the corresponding program unit: data storage, forming of requests to other program units, different computations. The Routing sub-block performs a choice of required port for sending of messages at the final address specified in it and transfers the relevant data to the App block. In the managing routing agents, the Routing program subunit together with the App subunit creates the task computation route. The Queue program subunit creates the sequence of messages sent to the relevant port and consistently sends and receives them. The number of program subunits of this type depends on the number of devices connected to this device in the HDIPS simulation model.

At the model initialization, the routing table is formed for each of program units: for each program unit of net-work the shortest route in the network graph is determined using the Dijkstra's algorithm and the program unit identifier and the number of port from which the data should be directed for transmission along the shortest route for this program unit is entered in the routing table.

The HDIPS utilization statistics collection is launched by the managing agents. Each managing agent sends requests for the computational node utilization information at the present moment to the computational node next to it in the network graph. After receipt of a response from the computational node, the managing agent sends consolidated information on the network utilization at the timepoint t to the network utilization database program unit. Each database program unit keeps the obtained information for all computational nodes. This process repeats with the frequency set by the HDIPS simulation model parameters. At the computations route formation, the managing agent requests the network utilization data from the data base next to it [12,13].

Different optimum route selection algorithms can be implemented in the managing agents. A review of the simplest of them is given below.

1. At the receipt of the route formation request for the task, the managing agent sends a message with the utilization information request to the utilization database.
2. Until the database response is provided, the current task and all other tasks obtained later are put in the wait queue.
3. When the HDIPS utilization information is received from the utilization database, the route is computed for each of the tasks in the wait queue:
   a. The data on required computing capacities and software are obtained from the task profile.
   b. According to the current HDIPS utilization data, a suitable computational node having free capacities and required software is chosen.
   c. According to the set heuristics the optimum node is chosen from suitable computational nodes.
4. The task with computed route is transferred further along the route and is removed from the queue of computations.

3. Modelling results

The study reviews results of the HDIPS modeling with the following parameters: the number of task generators is 10, the task generation probability is 0.5 at the uniform distribution, the task generation time is distributed under the normal distribution rule with the average value of 30 seconds and the mean square deviation of 10 seconds; each of the node generators generates tasks of one of six types, types of the tasks are evenly distributed; the number of managing agents is 20, the number of computational nodes is 30, each unit equally possibly has one of three types of computing profiles; number of statistics data base program units - 1, number of decision-makers - 1.

Within the framework of the modeling, 2910 tasks were delivered to the decision-maker, the average task processing time is 5 seconds (modeling time is a conventional unit and may correspond to real time by means of parameterization of delays in the data processing and transmission).

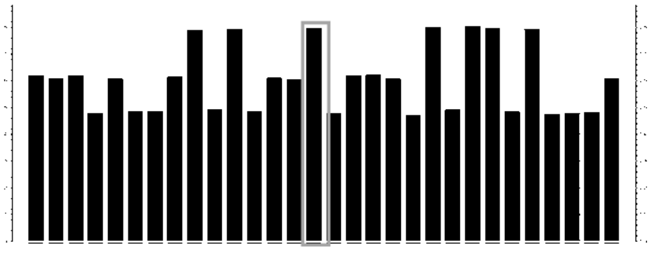

Figure 3. Ratio of the processed and destroyed tasks.

The tasks distribution algorithm at which the tasks which may lead to overloading of the computational node are destroyed was applied. figure 3 displays the ratio of tasks destroyed and processed by the computational node. The destroyed tasks are located in the first column of the pairs, the tasks processed during the simulation in second. At determination of the optimum resource allocation algorithm with the model, it is necessary to achieve the absence of tasks lost through overloading. In the illustrative purposes in this work the trivial algorithm described above was used.

The diagram in Figure 4 shows the average utilization of computational nodes of the HDIPS model. The index is determined as the resources utilization factor - the greatest percentage of utilization of one of three parameters: processor utilization, random access memory occupancy, hard drive occupancy. The order of units in figures 3 and 4 matches.

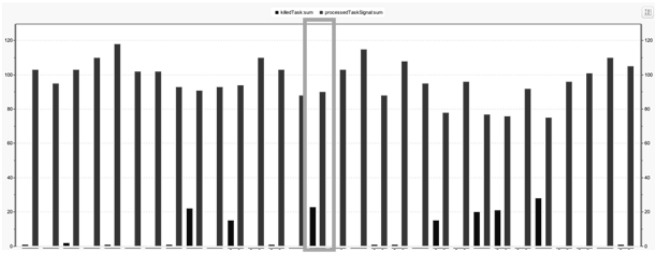

Figure 4. Average capacity of computational nodes.

Figure 5 shows the capacity of computational node No. 14 (marked with blue lines in figures 3 and 4) in the form of the resources utilization factor described above. For this type of unit, the minimum factor makes 0.7 according to the set input data. As it is supposed that because of a heterogeneity of the system the computational node is partially used for the tasks not associated with the task modeled in it, some of the computational capacity remains reserved. Line shows the top utilization - the tasks received at this moment are destroyed.

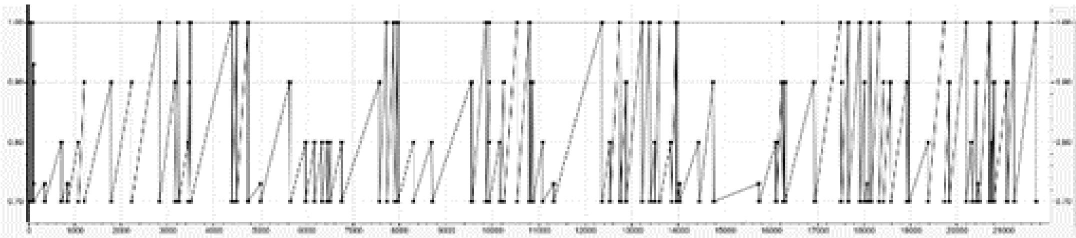

Figure 5. Server 14 Capacity Diagram.

4. Possibilities for further development of the model

Developed model allows to compare the efficiency of different resource allocation optimization algorithms in the HDIPS conditions and on the basis of the obtained data develop an intellectual resource allocation algorithm corresponding to the features of the system. Ample parameterization opportunities allow to use the HDIPS simulation model for modeling of real systems for both assessment of the current efficiency of their work, and for searching of the opportunities of its optimization - structural changes and new algorithms application. Implementation of the simulation model is rather productive for its use at modeling of real systems - the configuration of 1000 computational nodes may be easily launched on the personal computer.

5. Conclusion

Developed HDIPS simulation model represents a net-work made of the elements corresponding to the HDIPS functional elements. The model implements the basic algorithms for routing of network, collection and processing of the resources utilization statistics, and creates an opportunity for application of different load distribution optimization algorithms on its basis. Ample parameterization opportunities allow to model real systems with its help.

Acknowledgments
Results were obtained in the framework of the state task No. 2.5527.2017/8.9 of the Ministry of Education and Science of the Russian Federation.

References

[1] Ontugeva G A and Antamoshkin O A 2016 Modeling of the resource management system for a heterogeneous genebased distributed information processing system based on the multiagent approach *Siberian Journal of Science and Technology* **3** 602-10
[2] Gashnikov M B *et al* 2003 *Methods of computer image processing* (Moscow: Fizmatlit)
[3] Chernigovskiy A S, Tsarev R Y, Nikiforov A Y and Zelenkov P V 2016 *IOP Conf. Ser.: Mater. Sci. Eng.* **155(1)** 012042
[4] Kovalev I V, Zelenkov P V, Karaseva M V, Tsarev M Y and Tsarev R Y 2015 *IOP Conf. Ser.: Mater. Sci. Eng.* **70(1)** 012009
[5] Zhbanova N Y, Kravets O J, Grigoriev M G and Babich L N 2015 Neuro-fuzzy modelling and control of multistage dynamic processes that depend on inputs with uncertainty elements *Journal of Theoretical and Applied Information Technology* **80(1)** 1-12
[6] Kazakovtsev L A 2015 Algorithm for Weber problem with a metric based on Initial Fare *Journal of Applied Mathematics and Informatics* **33(1)** 157-72
[7] Antamoshkin O, Kukarcev V, Pupkov A and Tsarev R 2014 Intellectual support system of administrative decisions in the big distributed geoinformation systems *14th International Multidisciplinary Scientific Geoconference and EXPO SGEM 2014* **1** 227-32
[8] Kravets O Y, Makarov O Y, Oleinikova S A, Pilotin V M and Choporov O N 2013 Switching subsystems within the framework of distributed operational annunciator and monitoring systems: program design features *Automation and Remote Control* **74(11)** 1919-25
[9] Engel E, Kovalev I and Kobezhicov V 2015 *IOP Conf. Ser.: Mater. Sci. Eng.* **94(1)** 012009
[10] Kazakovtsev L A 2012 Modified genetic algorithm with greedy heuristic for continuous and discrete p-median problems Sixth UKSim/AMSS *European Symposium on Computer Modelling and Simulation* **30** 109-14
[11] Chernigovskiy A S, Tsarev R Y and Knyazkov A N 2015 Hu's algorithm application for task scheduling in N-version software for satellite communications control systems *International Siberian Conference on Control and Communications, SIBCON 2015 - Proceedings* 7147270
[12] Antamoshkin O A, Antamoshkina O A and Smirnov N A 2016 *IOP Conf. Ser.: Mater. Sci. Eng.* **122** 012003
[13] Antamoshkin O A 2012 Technology of distributed computer systems resources allocation *Management systems and information technologies* 48(2) 220-4