ABSTRACT

thesis of Satymbekov Maxatbek
on the topic: **« Development of multi-agent grid system Agent-GRID with dynamic load balancing of cluster nodes »**
submitted for the degree of Doctor of Philosophy (PhD) in the specialty 6D060200 – « Computer Science»

Relevance of the research topic. In recent years, “green” technologies (Green computing), or, as they say, “ecologically clean” technologies, have been going and rapidly advancing around the world. Today, not only engineering companies, but also when describing any new technologies, depending on environmental factors, use such indicators as energy saving, low carbon dioxide emissions into the environment and resource conservation.

San Murugesan explains green computing as “learning and practicing the design, manufacture, use, and disposal of computers, servers, and associated subsystems such as monitors, printers, storage devices, and networking and communications systems efficiently and cost effectively, or the same technologies that do not affect the environment”. As we can see, this definition includes words such as computers and environment. Global data center electricity use has been growing over the years. This growth was faster than the company's revenue, so it would ultimately lead to financial losses. 50% of electricity consumption belongs to the infrastructure of the site. After that, the volume of servers is about 30%, and the remainder is distributed among network equipment, storages, high-end servers and mid-range servers. This study found that the infrastructure used is costly for the company.

Today, in any educational institution, every employee or student has executive computing devices that are connected to each other locally and globally. Clusters may not be available, but there is a scientific need. In this case, you can use an architecture that allows you to use available devices to solve computational problems. Voluntary computing platforms provide this functionality through the use of voluntary resources. These solutions are usually designed to adapt to an ever-changing infrastructure topology and site structure. This research is motivated by the fact that when clustered systems may not be available, although there is an urgent need for high performance computing solutions. It is formally formulated in the form of the following thesis:

First, you can successfully use voluntary computing to solve high-performance problems. The solution uses the resources of users' mobile and personal devices, and its computational efficiency is comparable to traditional cluster systems.

Second, the core of voluntary settlements is that they allow users to use their own devices, which may contain the following resource usage criteria:

• Government officials (such as clerks, officials, etc.) can be required to provide their resources as part of their responsibilities.

• Users can receive payment (monetary reward) for the fact that they can use their resources

Thus, the creation of a multiagent grid system Agent-GRID is considered for using the resources of voluntary computer networks provided by users. Each computing node can change its characteristics at any time, depending on the actions of the owner. Therefore, modern approaches to the organization of grid systems do not allow taking into account such dynamic changes in the parameters of computational nodes that reduce its efficiency when creating a grid system using a database of computational nodes. Of course, this is a complex system that ensures efficient loading of such a homogeneous GRID network when solving problems in the case of rapidly changing parameters of individual computing nodes. From the above, we can conclude that for the effective solution of connected tasks in GRID, built on the basis of an IED with dynamically variable parameters, it is necessary to organize the GRID dispatcher in such a way that the times for selecting the IED and the distribution of subtasks between them are minimal, changes in the IED's performance are prompt were tracked, and the transfer of data from subtask to subtask was carried out directly. All these features can be implemented if the GRID dispatcher is based on the principles of multi-agent interaction.

The purpose of the dissertation work: Research and development of methods for organizing GRID systems using the properties of self-learning and self-organization of a multi-agent system.

Research objectives:

- analysis of methods for organizing GRID systems;
- Improvement of the GRID architecture based on a multi-agent system.
- development of an algorithm for creating a coalition of agents to solve custom tasks;
- Application of the developed methods in the experiment and analysis of the results.

Object of study. Training and self-management in a multi-agent system, workload distribution based on multi-agent systems of arbitrary structure.

Subject of study: A multi-agent system that uses the resources of mobile, personal computers to organize and perform resource-intensive tasks.

Research methods: For testing, the Java programming language is proposed, used in combination with the Java Agent development environment (Jade) libraries. Machine learning algorithms, methods of collective decision making, the theory of creating multi-agent systems, all data that is collected during the testing phase are visualized and thoroughly analyzed.

Scientific novelty of the work: A method for organizing the work of a GRID system using a multi-agent system, an algorithm for creating a coalition for solving user problems, and an extended algorithm for adaptive distribution of problems are proposed.

The theoretical and practical significance of the work. the theoretical results of the dissertation contribute to a body of knowledge in the field of applied artificial intelligence and the design of complex systems. In particular, they provide important information about load balancing in high-performance infrastructures.

The practical significance of the work. Creation of GRID systems based on the resources of private owners (computers, mobile devices), the fact that they do not require large costs, such as maintenance and replacement of computers, reduces the

cost of calculation. Reducing costs due to the absence of expensive service servers and infrastructure for their maintenance in the system.

The main provisions for the defense. the method of organizing a multi-agent approach, allows to increase the productivity of resources in a dynamically changing GRID-system.

Volume and structure of work. The dissertation consists of an introduction, three sections, a conclusion and a list of references. The total volume of the thesis: 93 pages of written text, including 14 figures, 6 tables, bibliography from 83 sources, 3 annexes.

The introduction substantiated the relevance of the topic, determined the object of research, formulated the goal, the main scientific results and provisions put forward for defense, shows the practical significance, approbation and results of the dissertation implementation.

In the first thesis is devoted to the development of principles and methods of multi-agent organization of work of grid systems

The second is devoted to the development of methods for organizing multi-agent interaction in the implementation of individual stages of the method of multi-agent organization of resources in GRID, proposed in the first chapter.

In the third analyzes and compares the results of multi-agent systems and algorithms created when organizing a GRID system.

In the conclusion the main results and conclusions of the dissertation research are presented.

Reliability level and testing results. The validity and reliability of the study correspond to the substantiated responsibilities of the task, the analysis of the criteria and the state of research in this area, a large number of experiments, and their successful implementation in practice. The results of the dissertation were discussed and reported at the following scientific and methodological conferences:

1. INFORMATIZATION OF THE SOCIETY, V international. Scientific and practical conference (2016, Astana, Kazakhstan).

2. International conference Youth and Science (2015, Pavlodar, Kazakhstan);

3. Conference of IIVT MES RK "Modern problems of informatics and computing technologies" June 29-30, 2017 (Almaty, Kazakhstan);

4. XIV International Asian School-Seminar "Problems of Optimization of Complex Systems" July 20 - July 31 (2018, Issyk-Kul, Kyrgyzstan);

5..2017 IEEE 14th International Scientific Conference on Informatics, Poprad, 2017;

6.5th International Conference on Mechanics and Mechatronics Research (2018, Japan);

On the topic of the dissertation, 17 articles were published and 2 copyright certificate were obtained:

1. V. Siládi, M. Povinský, L. Trajtel' and M. Satymbekov, "Adapted parallel quine-McCluskey algorithm using GPGPU," *2017 IEEE 14th International Scientific Conference on Informatics*, Poprad, 2017, pp. 327-331. doi:10.1109/INFORMATICS.2017.8327269.

2. M. N. Kalimoldayev, V. Siladi, M. N. Satymbekov and L. Naizabayeva, "Solving mean-shift clustering using MapReduce Hadoop," *2017 IEEE 14th International Scientific Conference on Informatics*, Poprad, 2017, pp. 164-167. doi: 10.1109/INFORMATICS.2017.8327240.

3. A Yeleussinov, T Islamgozhayev, M Satymbekov and A Kozhagul, “CVCER: Robot to Learn Basics of Computer Vision and Cryptography”, 5th International Conference on Mechanics and Mechatronics Research (ICMMR 2018) ,417 (2018) 012013 doi:10.1088/1757-899X/417/1/012013.

4. Siládi, M. Povinský, L. Trajtel' and M. Satymbekov, "Adapted parallel quine-McCluskey algorithm using GPGPU," *2017 IEEE 14th International Scientific Conference on Informatics*, Poprad, 2017, pp. 327-331. doi:10.1109/INFORMATICS.2017.8327269.

5. M. N. Kalimoldayev, V. Siladi, M. N. Satymbekov and L. Naizabayeva, "Solving mean-shift clustering using MapReduce Hadoop," *2017 IEEE 14th International Scientific Conference on Informatics*, Poprad, 2017, pp. 164-167. doi: 10.1109/INFORMATICS.2017.8327240.

6. Сатымбеков М.Н., Үлестірілген ортада агенттерді оқыту алгоритмі, Вестник КазАТК № 2 (97), 2016.

7. М.Н. Сатымбеков, И.Т.Пак, А.М. Мукышева, Көпагентті жүйені қолдану арқылы кластер тораптарының жүктемелерін оңтайландыру, Вестник КазАТК № 2 (101), 2017

8. Ж.Н. Оразбеков, Ч.А. Нуржанов, М.Н. Сатымбеков, Ж.Б. Султанғазы, Г. Тлеубердиева, Корпоративтік портал өндірістік деректер ағынын өңдеу процесінің anylogic ортасында имитациялық модельденуі, Труды Университета ҚарМТУ *№1 (70) 2018.*

9. Шаяхметова А.С., Сатымбеков М., Анализ современного состояния рынка программных продуктов по байесовским сетям, новости науки казахстана Научно-технический журнал, № 2 (136), Алматы 2018

10.Naizabayeva L., Orazbekov ZH.N., Nurzhanov CH.A, M. N.Satymbekov, G. Turken, Distributed database for corporate information control system over enterprises network, №2 2018 Вестник КазНИТУ.

11.M.N. Satymbekov, I.T. Pak, L. Naizabayeva, and Ch.A. Nurzhanov Multi-agent grid system Agent-GRID with dynamic load balancing of cluster nodes, Open Engineering. 2017; 7:485–490.

12.Сатымбеков М.Н. Үлестірілген ортада агенттерді оқыту алгоритмі, Еуразия Ұлттық Университеті, ИНФОРМАТИЗАЦИЯ ОБЩЕСТВА, V международная. Научно-практическая конференция, Астана,2016.

13.Сатымбеков М.Н., Gaia технологиясын пайдаланып жаңалық тарату көпагентті жүйесін жобалау, Международная конференция Молодежь и Наука, Павлодар, 2015.

14.Сатымбеков М.Н., Нуржанов Ч.А., Клеточные автоматы, МАТЕРИАЛЫ научной конференции ИИВТ МОН РК «Современные проблемы информатики и вычислительных технологий» 29-30 июня 2017 года.

15.Сатымбеков М.Н., Шаяхметова А.С., ДЕРЕКТЕРДІ КЛАСТЕРЛЕУ КЕЗІНДЕ БАЙЕСТІК ЖЕЛІНІ ҚОЛДАНУ, XIV Международной Азиатской школы-семинара «ПРОБЛЕМЫ ОПТИМИЗАЦИИ СЛОЖНЫХ СИСТЕМ» 20 июля – 31 июля Алматы 2018 г.

16.Bykov, M.M., Kovtun, V.V., Smolarz, A., Junisbekov, M., Targeusizova, A., Satymbekov, M., Research of neural network classifier in speaker recognition module for automated system of critical use (2017, Proceedings of SPIE - The International Society for Optical Engineering, *Wilga; Poland; 28 May 2017-6 June 2017.*

17. Druzhinin, A., Ostrovskii, I., Liakh-Kaguy, N., Zyska, T., Tuleshova, A., Satymbekov, M., Iskakova, A. Thermoelectric properties of SiGe whiskers with various morphology (2017, Proceedings of SPIE - The International Society for Optical Engineering, Wilga; Poland; 28 May 2017-6 June 2017.

The copyright certificate and act of implementation were received:

1. Computer program "Simulation model of data exchange and processing of a specialized corporate portal" copyright certificate No. 2932 dated December 6, 2017.
2. Computer program "BayesClass" copyright certificate No. 4198 dated June 24,2019.