Adaptive control methods

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MULTIAGENT METHODS OF MANAGEMENT OF DISTRIBUTED COMPUTING IN HYBRID CLUSTERS

Abstract. Modern information technologies include the use of server systems, virtualization technologies, communication tools for distributed computing and development of software and hardware solutions of data processing and storage centers, the most effective of such complexes for managing heterogeneous computing resources are hybrid GRID- distributed computing infrastructure combines resources of different types with collective access to these resources for and sharing shared resources. The article considers a multi-agent system that provides integration of the computational management approach for a cluster Grid system of computational type, the nodes of which have a complex hybrid structure. The hybrid cluster includes computing modules that support different parallel programming technologies and differ in their computational characteristics. The novelty and practical significance of the methods and tools presented in the article are a significant increase in the functionality of the Grid cluster computing management system for the distribution and division of Grid resources at different levels of tasks, the ability to embed intelligent computing management tools in problem-oriented applications. The use of multi-agent systems for task planning in Grid systems will solve two main problems - scalability and adaptability. The methods and techniques used today do not sufficiently provide solutions to these complex problems. Thus, the scientific task of improving the effectiveness of methods and tools for managing problem-oriented distributed computing in a cluster Grid system, integrated with traditional meta-planners and local resource managers of Grid nodes, corresponding to trends in the concept of scalability and adaptability.

Keywords: multiagent control; distributed computing; GRID; Grid clusters; multiagent modeling; intelligent agent; multiagent system; meta-planners; simulation.

Introduction

Common meta-planners do not fully take into account the specific requirements of users for resources when allocating these resources. Therefore, administrators and users of distributed computing environment resources have to "manually" solve the problems of selecting and providing resources, which can be quite versatile. This causes difficulties in solving these problems and raises the problem of automating and intellectualizing the processes of solving them. The most popular approach to solving this problem is the use of multi-agent systems (MAS) to control computing [1]. In this paradigm, two main approaches to multi - agent computing management can be distinguished [2]: interaction of the MAS with local resource managers of Environment nodes in order to optimize resource use and integration of a user application with a multi-agent resource selection system, the purpose of which is to increase the efficiency of problem solving by the application.

Currently, there is a wide range of tools for building distributed computing environments. These include, for example, general-purpose Google App Engine, Amazon EC2, Microsoft Azure, specialized Unicore systems, Globus Toolkit, Math Cloud, the Opa programming language, and systems implemented based on the Intelligent Problem-Solving Environment concept. The main direction in systems for building distributed computing environments is usually done to simplify the process of creating services. In such systems, computing management is implemented either using common meta-planners such as Workload Management System or Grid Way, or using specialized system tools. Thus, today it is relevant to apply a multi-agent approach for managing distributed computing at the Grid system level and computing at the application level.

Analysis of recent research and publications. Analysis of modern scientific and information sources in the field of computing management research of cluster grid systems of computational type. In the research of Kostromin R. A., Feoktistov A. G., The problems of multi-agent control systems for distributed computing are considered.

In [9] methods and tools for managing problem-oriented [8] distributed computing in a cluster Grid system are used. Bychkov I. V. [11] focus their analysis on well-known methods of multi-agent control of a computing system based on meta-monitoring and simulation.

According to the construction principle, there are analytical, simulation, and statistical mathematical models.

Analytical models of control and metaplaning in Grid systems are described in the works of Toporkov V. V., Yemelyanov D. M., Toporkov A. S. [7], Batool K., Niazi M.A. [12], Budaev D., Amelin K., Voschuk G. [13], in which a mathematical, basic model of equations is created, and an approach to hybrid modeling using complex networks and agent-based models is considered.

However, the existing methods [6, 10] of managing planners in systems with a hybrid structure, in conditions of uncertainty [1, 5], require a large number of complex mathematical calculations [4, 3], so we consider methods of a multi-agent approach for managing distributed computing at the Grid system level and managing calculations at the application level distributed computing in a cluster Grid system, integrated with traditional meta-planners and local resource managers of grid system nodes to optimize the work of planners.

The aim of the study is to identify the features of applying multi-agent approach methods for managing distributed computing at the Grid system level and managing computing at the application level.

Main part

1. Managing calculations at the Grid system level. Computing management at the Grid system level is implemented by the MAS with a given organizational structure.

Agents' actions are coordinated using the general rules of group behavior. Agents function according to the specified roles, and each role has its own rules of behavior in the virtual community of agents. The MAS includes resource allocation agents and a management agent. Resource allocation agents can be combined into virtual communities (VC). In the various VC that arise in the MAS, agents can coordinate their actions through cooperation or rivalry. The task of the MAS at the Grid system level is to obtain such a distribution of task flows entering the system and store indicators of the quality of functioning of this system within the limits set by the Grid system administrator.

A task is a specification of the problem - solving process that contains information about the necessary computing resources, running application programs, input and output data, and other necessary information. All tasks are divided into classes according to their computational characteristics [2].

Indicators of the quality of functioning of the Grid system include: average indicators of time spent in queues, useful coefficients of nodes of the Grid system and the system as a whole, successful completion coefficient and the average cost of performing tasks of different classes in nodes of the Grid system and in the system as a whole.

A block diagram of the computing management system at the Grid system level is shown in Fig. 1.

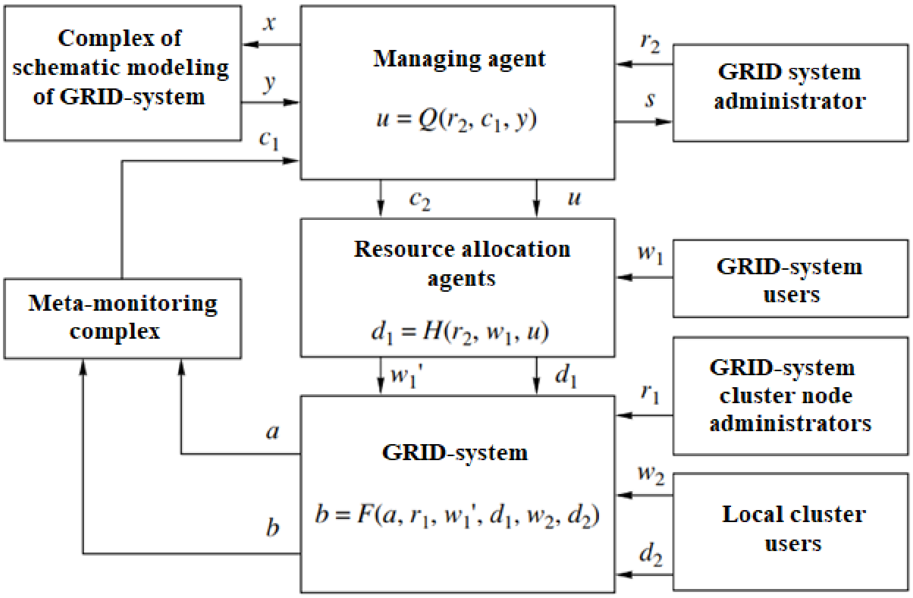

Fig. 1. Block diagram of the computing management system

In this diagram, the control object is a Grid system, the nodes of which are represented by heterogeneous computing clusters (CC), including hybrid ones. External perturbations for the control object are the flow w_1 grid system user tasks and flow w_2 local users of computing clusters. Distribution results d_1 and d_2 flows w_1 and w_2 CC software is the control effect of MAS and local users of the computing cluster on the control object, respectively. The specified action for the control object is the vector of parameters of administrative policies of the computing cluster r_1.

Resource allocation agents intercept thread tasks w_1 in order to configure the computer system requirements contained in tasks in more detail. So, the flow w_1 modified into a flow w_1'. Distribution d_1 flow w_1' it is carried out by resource allocation agents on the basis of economic mechanisms for regulating the supply and demand of these resources [3]. Distribution d_2 flow w_2 set by local CC users.

Task flows w_1 and w_2 they are characterized by the following properties: dynamism; heterogeneity; lack of feedback; originality; stationarity.

Information about the computational characteristics of Grid system nodes is collected by a meta-monitoring Complex [4] using Control and measuring devices in the form of a data file structure a. Information about the current indicators of the volume of computing work in the nodes of the Grid system is also collected by the meta-monitoring complex in the form of a data file structure b. It is assumed that between the components of structure b on the one hand and the computational characteristics of nodes a, given by the action r_1 for the task flow management object w_1' and w_2, distributions d_1 and d_2 on the other hand there is some abstract connection

$$\mathrm{b} = \mathrm{F}(\mathrm{a}, \mathrm{r}_1, w_1', \mathrm{d}_1, \mathrm{w}_2, \mathrm{d}_2).$$

Parametric configuration of algorithms for the operation of resource allocation agents of a particular virtual community is carried out by applying the obtained control actions, taking into account weighting factors that reflect the computational features of virtual community nodes.

Therefore, let *x* and *y* be the vectors of the input and observed variables of the Simulation Model [7] of the Grid system.

The observed variables reflect indicators of the quality of functioning of the Grid system. Vector elements x_i , $i = \overline{1, n_x}$ and y_j, $j = \overline{1, n_y}$ have respectively areas X_i and Y_j valid values.

It is assumed that the effects of the input variables on the observed variables were studied using factor analysis [5] in advance - when building and testing a simulation model of a Grid system. It is also assumed that for each j-th element of the vector y the administrator of the Grid-system sets the criterion for calculating the estimate y_j quality of value and its limit values y_j^{min} and $y_j^{max} \epsilon Y_j$.

A number of elements of the vector x play the role of variable variables, forming a subset X^* and are identified with the elements of the vector

$$u{:}\, u_q \equiv x_i,$$
$$q = \overline{1, n_u}, i \in \overline{1, n_x}, 1 \le n_u < n_x .$$

As a rule, when solving practical problems of computational control in the Grid system in the process of simulation, it is advisable to use ≤ 8 . The number of values of variable variables is determined based on the ratio:

$$\frac{t_m \times \prod_{q=1}^{n_u} z_q}{n_c} \le T_2, \quad (1)$$

where t_m - the average run time of the simulation model, which is determined by the meta-monitoring complex based on the computational history of the model runs, $z_q < 0$ - the number of variable values of the q-th variable, n_c - the number of cores of the node in which the control agent is located, $n_u < n_c$.

The initial values of the variables used are the base values that correspond to the default values of the configuration parameters of the current Grid computing control system.

The remaining values of the variables are selected from the relevant areas of allowable values, taking into account the effects of the influence of variable variables on the observed variables.

The values of non-variable input variables, which are elements of the vector x, are set based on the corresponding numerical information represented by the vectors r_2 and c_1.

In the process of modeling the simulation of the process of functioning of the Grid-system is performed by conducting various parallel calculations and a set of V variants of values of the observed variables is formed: values $y_{jk} \in Y_j$ is an element of the k-th variant $v_k \in V$ for the variable$y_j j = \overline{1, n_y}, k = \overline{1, n_v}$.

Selection from the set V of the subset $V^* \subseteq V$ variants of the values of the observed variables in order to further determine the values of the elements of the vector *u* is multicriteria.

Choice of options for the subset V^* carried out by the managing agent either on the basis of the lexicographic method, if the administrator of the Grid system can order the observed variables by significance, or otherwise on the basis of the majority method. The lexicographic method of selection of variants of values of the observed variables uses the following rule of multicriteria choice [6]:

$$V^* = \{v_k \in V{:} \left(\forall_{vl} \in V \exists p \in \overline{1, n_y - 1} : \right.$$
$$(\hat{y}_{1k} = \hat{y}_{1l}) \wedge \ldots \wedge \quad (2)$$
$$\left.\wedge \left(\hat{y}_{pk} = \hat{y}_{pl}\right) \wedge \left(\hat{y}_{(p+1)k} > \hat{y}_{(p+1)l}\right)\right) \},$$

where $y_j^{min} \le y_{jk} \le y_j^{max}$,

$$j = \overline{1, n_y}, \quad k \in \overline{1, n_v}, \quad l \in \overline{1, n_v}, \quad k \ne l.$$

The majority method of selection of variants of values of the observed variables uses the following rule of multicriteria choice [6]:

$$V^* = \{v_k \in V(\neg \exists v_l V{:}$$
$$\sum_{j=1}^{n_y} sign\left(\hat{y}_{jl} - \hat{y}_{jk}\right) > 0) \}, \quad (3)$$

where sign (0) = 0,

$$y_j^{min} \le y_{jk} \le y_j^{max},$$
$$j = \overline{1, n_y},\ k \in \overline{1, n_v},\ l \in \overline{1, n_v},\ k \ne l.$$

The application of the above methods of multi-criteria selection is due to the fact that they have the least computational complexity compared to other known methods of solving this problem, easy to implement and the managing agent requires minimal additional information from the Grid system administrator.

Thus, resource allocation agents exert managerial influence $d_1 = H\ (c_2, w_1, u)$ on the Grid system, where the control effect $u = Q(r_2, c_1, y)$ designed to improve the quality of decisions made by resource allocation agents by influencing the degree of intent of agents to perform tasks of different classes.

The *H* and *Q* bonds have the same nature as the F bond considered. It should be noted that in the event of failure of any MAS agent, including the control agent, the operation of the control object will continue [11].

At the same time, only the quality of his work may decrease.

2. Application-level computing management. Additional application-level computational management tools are a virtual application community that is created to run a parallel application of a local user program in a Grid system.

The main purpose of the virtual community application - providing a selection of the least loaded CC running a parallel application, monitoring and transmitting to the user the results of calculations. The virtual application community includes a custom agent, a classification and scheduling agent, an agent manager, and a dynamically changing set of local agents [10].

Necessary for the distribution of information about the computational characteristics of the nodes and the current indicators of the volume of computational work CC, presented as a vector c_2, the agent-manager receives from the managing agent.

The agent manager is also responsible for automatically restarting tasks with new settings and for monitoring the user's task execution process. For distribution of tasks on local agents the tender model where computational works act as lots, and as - representatives of the computing resources applying for performance of works acts.

In general, the service provides the user with the following options: task formulation, configuration and input of data for the program, obtaining calculation results, viewing the current CC load and receiving information messages by both mail and web interface. Along with the listed functions of system character in the created virtual community of application it is possible to consider the possibilities caused by specificity of subject area of application of the user. Local agents are responsible for sending tasks to the local CC management system, analyzing the current state of the CC and transmitting the results of the tasks to the agent-manager.

Conclusions

The article considers methods and tools for managing problem-oriented [8] distributed computing in a clustered Grid system [9], integrated with traditional meta-planners and local resource managers of Grid nodes, including original methods and tools for converting user-friendly queries in computational tasks, task classification and decomposition of environmental resources according to task classes.

These methods and tools have a number of distinctive features. First, they provide the ability to develop and implement application services in different modes: managing calculations both at the level of individual applications and at the level of task flows; allocation of resources required to perform service operations by special agents or traditional local resource managers, application of static or dynamic computational scheduling.

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Мультиагентні методи управління розподіленими обчисленнями у гібридних кластерах

В. П. Колумбет, О. В. Свинчук

Анотація. Сучасні інформаційні технології передбачають використання технологій серверних систем, технологій віртуалізації, комунікаційних засобів для розподілених обчислень та розроблення програмно-апаратних рішень центрів обробки та збереження даних, найбільш ефективними з таких комплексів для управління неоднорідними обчислювальними ресурсами є гібридна GRID-розподілена обчислювальна інфраструктура, яка об'єднує ресурси різних типів з колективним доступом до цих ресурсів для і спільного використння загальних ресурсів. У статті розглядається мультиагентна система, що забезпечує інтеграцію підходу до управління обчисленнями для кластерної Grid-системи обчислювального типу, вузли якої мають складну гібридну структуру. Гібридний кластер включає обчислювальні модулі, що підтримують різні технології паралельного програмування і розрізняються своїми обчислювальними характеристиками. Новизна і практична значущість представлених в статті методів і засобів полягають в істотному розширенні функціональних можливостей системи управління обчисленнями кластерної Grid за розподілом і поділу ресурсів Grid на різних рівнях виконання завдань, в наявності можливості вбудовування інтелектуальних засобів управління обчисленнями в проблемно-орієнтовані додатки. Застосування мультиагентних систем для планування задач у Grid системах дасть змогу розв'язати дві основні проблеми – масштабованості та адаптивності. Методи й прийоми, що використовуються сьогодні, не в достатній мірі забезпечують розв'язання цих складних проблем. Таким чином, актуальним є наукове завдання підвищення результативності методів та засобів управління проблемно-орієнтованими розподіленими обчисленнями в кластерної Grid-системі, інтегрованих з традиційними мета-планувальниками і локальними менеджерами ресурсів вузлів Grid-системи, що відповідають тенденціям розвитку концепції масштабованості та адаптивності.

Ключові слова: мультиагентне управління; розподілені обчислення; GRID; кластерні Grid; мультиагентне моделювання; інтелектуальний агент; мультиагентна система; мета-планувальники; імітаційне моделювання.

Мультиагентные методы управления разделенными вычислениями в гибридных кластерах

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Аннотация. Современные информационные технологии предполагают использование технологий серверных систем, технологий виртуализации, коммуникационных средств для распределенных вычислений и разработки программно-аппаратных решений центров обработки и хранения данных, наиболее эффективными из таких комплексов для управления неоднородными вычислительными ресурсами является гибридная GRID-распределенная вычислительная инфраструктура объединяет ресурсы разных типов с коллективным доступом к этим ресурсам и совместного использования общих ресурсов. В статье рассматривается мультиагентная система, обеспечивающая интеграцию подхода к управлению вычислениями для кластерной Grid системы вычислительного типа, узлы которой имеют сложную гибридную структуру. Гибридный кластер включает в себя вычислительные модули, поддерживающие различные технологии параллельного программирования и различающиеся своими вычислительными характеристиками. Новизна и практическая значимость представленных в статье методов и средств заключаются в существенном расширении функциональных возможностей системы управления вычислениями кластерной Grid по распределению и разделению ресурсов Grid на разных уровнях выполнения задач, налицо возможности встраивания интеллектуальных средств управления вычислениями в проблемно-ориентированные приложения. Применение мультиагентных систем для планирования задач в Grid системах позволит решить две основные проблемы – масштабируемость и адаптивность. Используемые сегодня методы и приемы в недостаточной степени обеспечивают решение этих сложных проблем. Таким образом, актуальна научная задача повышения результативности методов и средств управления проблемно-ориентированными распределенными вычислениями в кластерной Grid-системе, интегрированных с традиционными мета-планировщиками и локальными менеджерами ресурсов узлов Grid-системы, соответствующими тенденциям развития концепции масштабируемости и адаптивности.

Ключевые слова: мультиагентное управление; распределенные вычисления; GRID; кластерные Grid; мультиагентное моделирование; интеллектуальный агент; мультиагентная система; метапланировщики; имитационное моделирование.