BUILDING OF THE VIRTUAL ENVIRONMENT FOR GRID APPLICATIONS

Volodymyr Kazymyr, Dmytro Melnychenko, Olga Prila, Mykola Kryshchenko

***Abstract**: The article considers the problems of configuring grid resources to perform computational tasks in the grid environment. The technology of automated configuration environment to perform tasks in the grid environment using virtualization was proposed. The results of the evaluation of the effectiveness of the proposed technology based on the developed simulation model were presented.*

***Keywords**: grid-computing, virtualization, effectiveness, simulation.*

***ACM Classification Keywords**: C.2.4 Distributed Systems, D.4.1 Process Management.*

Introduction

Grid computing is a form of distributed computing, in which a virtual supercomputer is presented in the form of loosely coupled heterogeneous computing resources, connected to a global network and used to solve computational problems of large dimension. Using the idle capacity of distributed resources instead of increasing the power of local resources is a cost-effective solution.

Ukrainian national grid infrastructure consists of about 26 clusters. In recent years a number of projects of state scientific and technical program were carried out the purpose of which is the application of grid technologies for solving computational problems of various scientific fields such as astrophysics, molecular biology, physics, geochemistry, environmental monitoring, economic forecasting, population-based studies in the field of cardiology and other tasks. Virtual organization implies a dynamic community of people and organizations that share a dedicated set of grid resources in accordance with agreed rules for solving tasks of particular scientific field.

In the presence of a large number of computing tasks of different scientific areas that require significant computing power according to monitoring data (http://www.nordugrid.org/monitor/) to date there is a high percentage of idle resources of the Ukrainian national Grid infrastructure, which is primarily explained by the complexity of the processes of computational tasks preparation for solving in the grid environment as well as configuration the runtime environment for task execution on a remote computing resource. The article studies the following problems of using a distributed grid environment:

- the complexity of administration grid computing resources in the terms of configuring environments for different tasks' execution;
- the inability to execute computing tasks on grid resources using administrator privileges;

- the absence of full-featured high-level tools for the preparation and running computing tasks in grid environment;
- the problem of deployment licensed software on remote grid resources and using correspondent software for task execution;
- the incompatible versions of the operating systems (OS) running on a computing grid resource and those required for the execution of the user application task.

For example, there is often the need to perform computing tasks using the software under Microsoft Windows OS where as the server grid middleware is to use the Linux OS. The incompatibility of the required version of the OS with the hardware characteristics of grid resources is also possible.

EMI grid middleware providers (http://www.eu-emi.eu/) don't support automated environment configuration for computing task execution. Under the environment the requirements for the software to be installed on the computing resource for task execution are implied.

Using the virtual machine technology the virtual image (VI) with necessary settings can be formed and used when submitting and executing computing task on grid-resources. This will solve the problem of using licensed software in grid-environment and task execution with administrator privileges.

The important aspect of widespread using of grid technologies is to provide the required level of quality of service (QoS) that for a non-commercial environment is most often defined as the guaranteed time of successful calculations completion. The virtual machine technology using in grid-environment determines the problem of designing effective structure of virtual images distributed storage in grid-environment to minimize communication costs and the development of appropriate scheduling algorithms.

The usage of virtualization technologies when performing tasks in the grid environment

The term virtualization refers to the abstraction of computing resources and providing the user of the system that "encapsulates" (hides) your own implementation. The term virtual machine (VM) means a product of virtualization software and hardware platform. There are the following advantages [Bogdanov, 2008] [Jain, 2012] [Mann, 2006] [Romanova, 2011] of using virtualization:

- ability to create the required hardware configurations;
- ability to support legacy operating systems to ensure compatibility;
- on the same host could be running multiple virtual machines, connected into a virtual network;
- possibility of cloning and backup virtual machines.

The use of virtual machine technology in grid environments will allow users to form virtual image settings and define it as the virtual environment, which needed to perform a task on a remote grid resource.

Requirements for running tools of applied computational problems with the ability to define a virtual environment: the ability to define a virtual environment as a parameter the specification of the grid task, the search of the required virtual environment, transfer and deployment to a remote resource in an automated mode.

The authors conducted a research of existing technologies for constructing virtual environment for execution of computational tasks on a remote resource in a distributed environment according to the following criteria:

– transfer VI on the remote resource;
– store the virtual images in a distributed repository, including the presence of replication facilities;
– ability to select a virtual environment to complete the task;
– ability to solve computational tasks of various types (serial, parallel, data processing, workflows) [Prila, 2014] of different application areas;
– optimization of planning with the peculiarities of the distributed environment;
– a high-level interface;
– expandable.

Table 1 presents a comparative analysis of existing technologies of constructing virtual environments, such as Nimbus, skifGrid, Rainbow and the software package "virtual container".

Table 1 – Comparative analysis of existing technologies of constructing virtual environment

Assessment criterion	The software package "virtual container"	Skif Grid	Rainbow	Nimbus
Transfer VI on the remote resource	+	+	+	-
Store the virtual images in a distributed repository, including the presence of replication facilities	-	-	-	+
Ability to select a virtual environment to complete the task	+	-	+	+
Ability to solve computational tasks of various types	+	+	+	+
Optimization of planning with the peculiarities of the distributed environment	-	+	+	-
A high-level interface	-	-	-	+
Expandable	-	-	-	+

Notes:

1. “–” it means the absence of the implementation of this requirement in the considered decision.
2. “+” it means the presence of implementation of this requirement.

The Nimbus service package (http://www.nimbusproject.org) with open source allows users to run virtual machines on FutureSystems hardware, and focused on providing infrastructure as a service (IaaS) for the scientific community [Keahey, 2005].

Nimbus provides an implementation of cloud computing, allowing users to use computing resources by deploying virtual machines on these resources. Additional Nimbus tools provide the possibility of implementing scalable cloud storage.

Nimbus Context Broker implements the ability to create shared configuration resources, which are available from several clouds, distributed support providers. Such tools are oriented to work in a multi-user cloud environment and a combination of private and public cloud capabilities, called by sky computing tools.

Nimbus software package provides to developers a highly customizable and extensible implementation (IaaS) open source. For this Nimbus package supports different implementations of virtualization (Xen or KVM), resource management (including schedulers such as PBS), interfaces (including Compatibility with Amazon EC2 [Keahey, 2012]) and many other options.

Services package Nimbus does not support software for building cloud infrastructure, which is included in the standard EMI (ARC Nordugrid, gLite, Legion (http://legion.virginia.edu/index.html), Condor (http://www.cs.wisc.edu/condor/), Unicore (https://www.unicore.eu/about-unicore/)) and used in the Ukrainian national grid (UNG). Focusing on the use of cloud infrastructure determines the complexity extensions for use in diverse heterogeneous grid environment.

The software package Rainbow («ARC in the Cloud») was developed within the project the UNG for tasks of interactive analysis of medical data "Medgrid" virtual organization (http://medgrid.immsp.kiev.ua/). The app is aimed at hardware acceleration of virtual machines on the worker nodes of the cluster and focused on the use of middleware software (middleware) Nordugrid ARC. A processor computing element and manager work cycle of a virtual machine used RunTimeEnvironment mechanism (RTE) of software Nordugrid ARC [Ellert, 2007].

The implementation uses the finished elements network infrastructure the Linux operating system. Interactive access to platforms based on Windows is performed by using a remote connection protocol to RDP desktop.

Rainbow provides the end user with several file-sharing scenarios with the virtual machine. If data access is needed only in the read mode, the ISO method allows you to connect a virtual CD-ROM with the files. To access the recording mode DISK method connects the virtual hard disk to a predetermined size and selected file system. Transferring files, resulting from the work, back to the Grid environment in a similar way - the files are extracted from the virtual disk and transferred to stage-out mechanism of the software grid. The software package Rainbow presents RPMs in repository [Salnikov, 2015].

However, the solution is focused on starting and completing specific computational tasks of medical data analysis and involves the use of the same type VI, pre-installed on the grid resource. Software Rainbow does not include the possibility of extensibility.

Middleware SKIF-GRID (skifGrid) (http://grid.basnet.by/projects/skifgrid/wiki) is designed to unite distributed high-performance computing resources in a unified grid network and for the organization of user access to virtualized server platforms.

Unlike middleware included in the EMI standard, components skifGrid realilized the possibility of a virtual service organization.

Components skifGrid:

– skifGrid-srv is designed to virtualize server hardware and system management of virtual servers, uses the implementation of middleware Ganeti (http://code.google.com/p/ganeti);
– the manager of computing resources (skifgrid-crm) uses middleware QosCosGrid (http://www.qoscosgrid.org);
– broker computing resources (skifgrid-crb);
– the client console access resources (skifgrid-cli);
– monitoring of the grid network (skifgrid-mon).

Middleware skifGrid is free software that is allowed to distribute and modify in accordance with the terms of the GNU General public license (GPL) version 3 (http://www.gnu.org/licenses/gpl-3.0.html).

The installation files are represented by packages .deb in repository, however, the distributions skifGrid not available, which hampers the possibility of expanding the tool.

Also were developing in the research computing centre of Moscow state University M. V. Lomonosov on using virtual machines in grid technologies for solving problems in computational chemistry. This concept describes the use of virtual machines as the outgoing distributed tasks, which provides the user with the required quality of service, without affecting the operation of the main components of resource services. Thus, the user of a distributed environment may be provided by a fully isolated virtual computing environment (virtual container). The properties of a virtual «container» are not inferior to the physical server, in which any of its own computing service can be provided. In this application, implemented in the VM, it means absolutely no dependence on the operating system and environment. Also it considered as the complete separation of a specific service or program from the external environment, and the environment from it. This is possible through the use of an additional layer of software – the virtual hardware, allowing carrying out a regular application, as if it were running on a separate computer.

The user is able to create a virtual machine image with preinstalled operating system and fully configured applications aimed at solving a specific problem. This image is transmitted to a distributed resource, and there is executed as a grid application, without the need for configuring this node for specific tasks. This greatly facilitates the adaptation of application software to operate in distributed environments. An additional advantage is the fact that these technologies make it possible to run virtual machine images with operating systems that are different from those installed on the resources [Volohov, 2009].

However, this method is considered to use virtual machines for specific tasks in computational chemistry. Also this concept was not considered the option of using a high-level interface.

Technology automated configuration environments in grid resources

The virtual machine technology will allow generating a virtual image with the settings and using it when launching and running computational tasks on the grid resources. This is a solution to the problem of using the licensed software for solving tasks in grid-environment.

The authors planned the practical implementation on the existing framework for the development of grid applications [Kazymyr, 2013] with the use of the developed technology. Technology needs to provide the following services (Fig. 1):

1. The formalization of the parameters of the VM environment.

Before submitting a request to the task execution in the grid environment, a user or automated select a number of hardware and software options. Further are given the opportunity to use it for the desired software applications in the relevant grid resources.

2. The possibility of determining the required VM image to perform the task.

3. The initial load of the image.

Also it should be transmitted the image of a virtual machine, if previously it was not transmitted in the previous tasks. A description of the task and the task itself are sent in the form of a virtual image to meta scheduler of grid.

Figure 2 shows the architecture of the framework for the creation of grid-enabled applications of modern grid middleware, which has been extended by the following modules: module of accommodation VI, scheduling tasks module with the use of VI, statistics module.

Services scheduling tasks module with the use of VI implements automatic search for the desired VI. And it selects of computing resource for image deployment, and task execution.

The parameters collected (most requested tasks for execution in the grid environment) by the statistics module used in the design of the replication scheme VI. The mechanism for deployment on remote computing resources is implemented with using a software platform OpenNebula (http://opennebula.org).

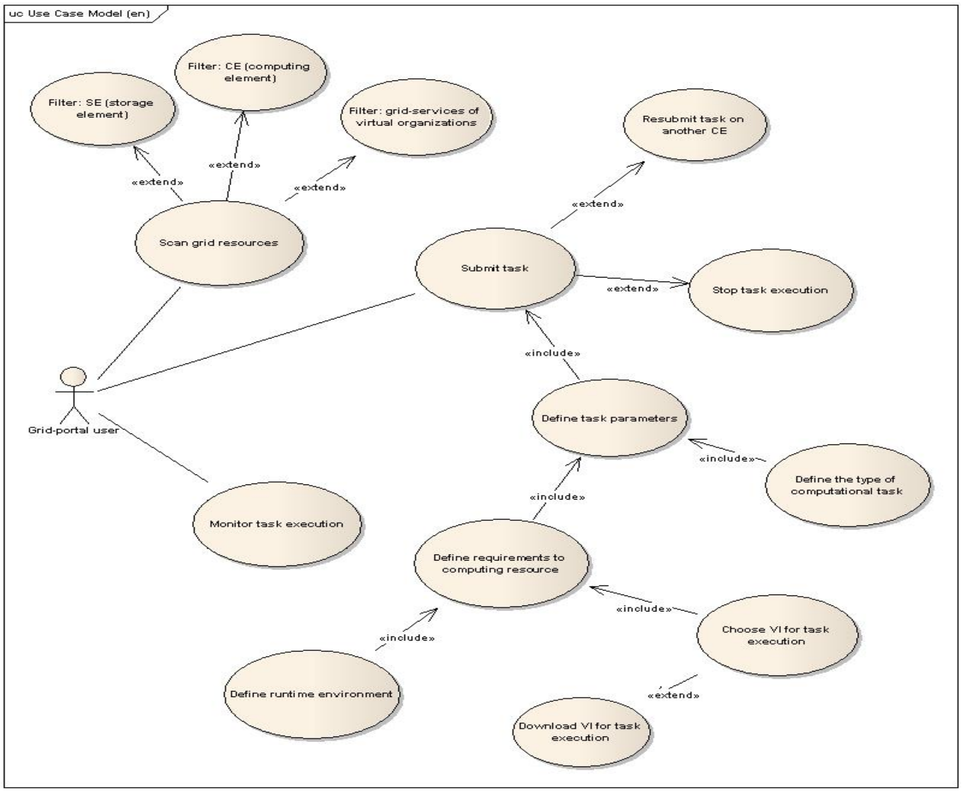

Figure 1. Expansion of the framework of services for the development of high-grid applications.

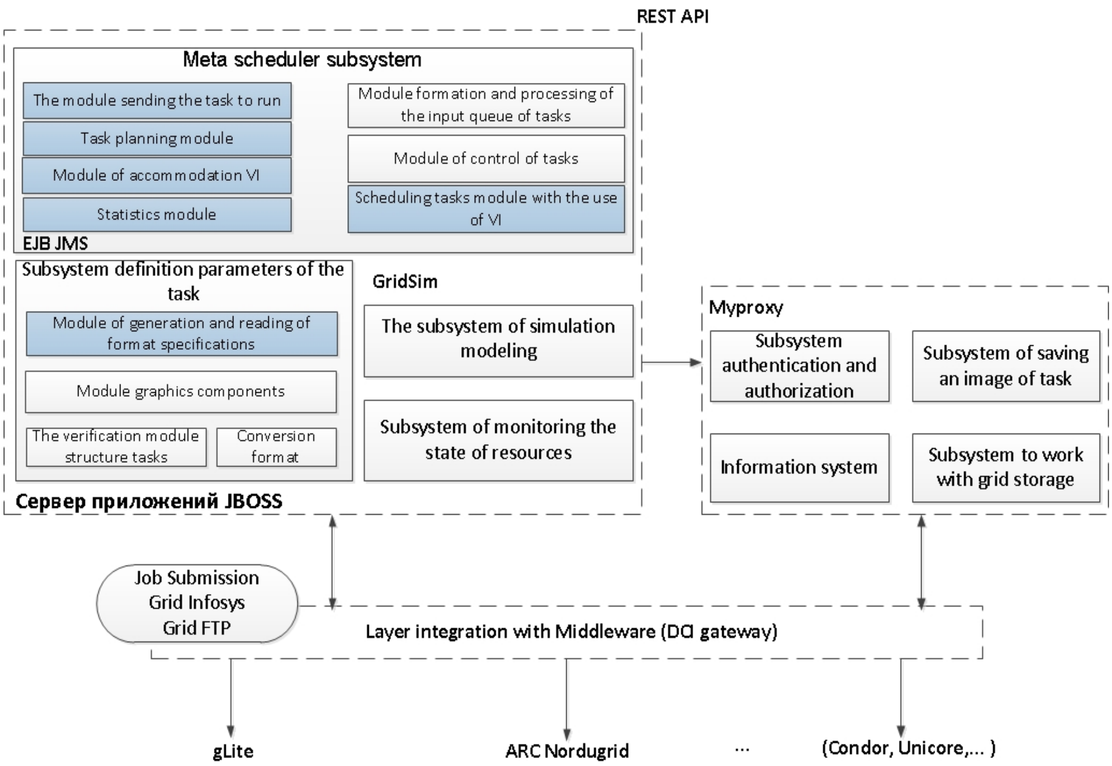

Figure 2. Architecture of a framework for the development of grid applications

Module of accommodation VI determines computing resource to store the virtual image.

A simulation model of grid environment using virtualization

A parallel application is generally modeled by a precedence-constrained task graph, which is a directed acyclic graph with node and edge weights. In this model a task cannot start execution before all of its parents have finished their execution and sent all of the messages to the machine assigned to that task [Forti, 2006].

To assess the effectiveness of the approach was developed process model tasks in grid-environment using virtualization technology based on simulator GridSim [Buyya, 2002]. When developing the above model, a simulation model of grid environment [Bivoyno, 2013] was extended with the following options:

1. Size of the virtual image (for OS Linux this value is 1.5-4 GB and >= 4 GB for Windows OS, etc.).
2. Time on deployment VI. Figure 3 shows the time estimation to deploy virtual images using Oracle VM VirtualBox 5.0.14 (https://www.virtualbox.org/) with the following characteristics (Table 2). Experiments the evaluation time on deployment VI was conducted in a real environment.

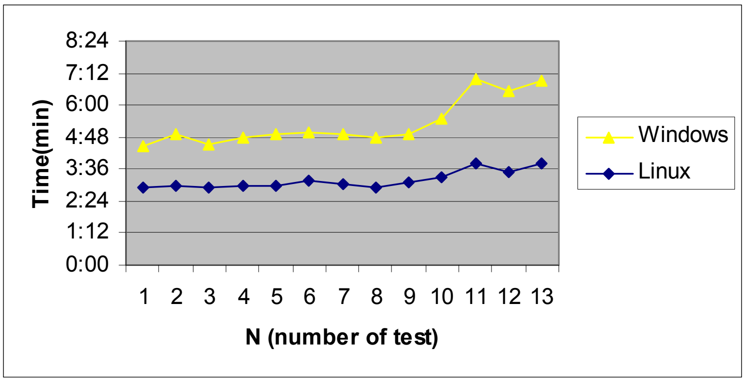

Figure 3. Evaluation time for the deployment of virtual images.

The x-axis in figure 3, N is the number of the experiment.

Table 2 – The characteristics of the tested virtual images.

Settings	Linux	Windows
OS	Ubuntu 14.04 64 bit	Windows 7 64 bit
RAM	1024 MB	1024 MB
Load Order	Net, HDD, Optical disk	Net, HDD, Optical disk
Acceleration	VT-x/AMD-V, Paravirtualization, KVM	VT-x/AMD-V, Paravirtualization, Hyper-V

3. Transmission time to send VI on the grid resource. Test results on the transfer VI from the client to the server grid.stu.cn.ua over TCP using the cantilever cross-platform client-server utility iperf (https://iperf.fr/iperf-doc.php) confirmed a linear relationship between the amount of size of VI and the time of transmission.
4. Time of transfer grid task from virtual machine to compute resource. As with the previous experiment, the authors used the iperf utility, the results presented in figures 4-5.

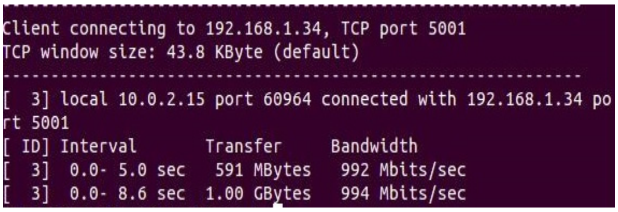

Figure 4. Network bandwidth parameter when the transmission of VI on the side of VM

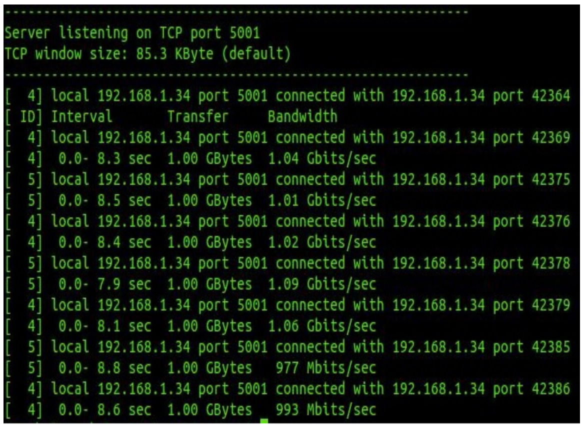

Figure 5. Network bandwidth parameter when the transmission of VI on the side of the main machine

Next, we consider the results of the simulation of task execution in grid environment using virtualization technology on the basis of GridSim simulator.

The input parameters of the extended simulation model the following:

– size of VI;
– the transmission time to send VI;
– time of transfer grid task from virtual machine to compute resource.

In the experiment the value of the parameters of the model are the following: size of VI is equal to 1GB, the transmission time to send VI – 190 minutes, time of transfer grid task from virtual machine to compute resource – 8.3 sec. The augmented model consists of one user and the grid resource on which tasks are performed. Tasks (Task) are performed simultaneously in a queue.

Figure 6 shows the comparison of time execution of tasks in grid and with a run time of grid tasks, given that VI is already on a remote computing resource.

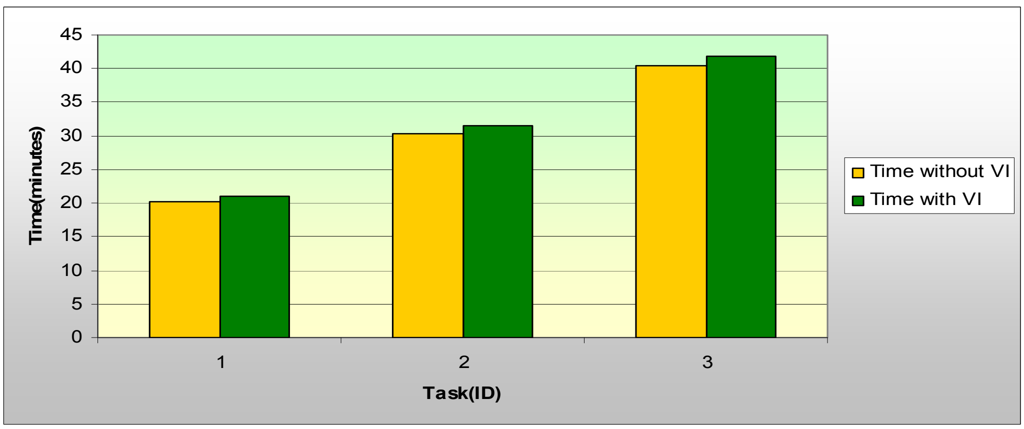

Figure 6. Execution time of tasks in the grid environment without using virtualization, pre-installed virtual image on the remote resource.

Where Time is the execution time of tasks in the grid environment, Time without VI – the time of the task without the use of virtualization and Time with VI refers to the time duration of the task execution provided that, if VI is already on the grid resource. Under the units of Time values in figure 6 refers to minutes.

According to the obtained results (Fig. 6), we can say that the time spent on task execution in grid environment using virtualization does not exceed 5 % than the cost of performing the task without the use of virtualization in the grid environment.

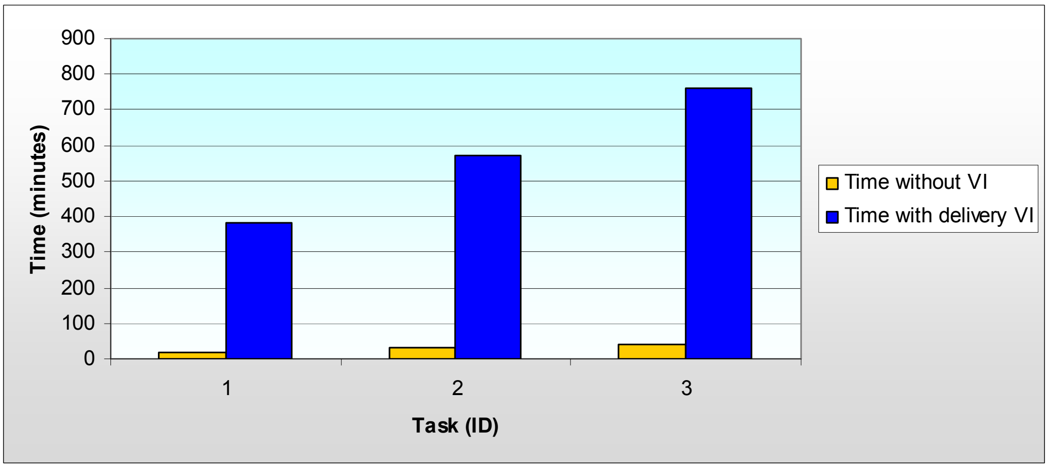

Figure 7. Execution time of tasks in the grid environment without and with the use of virtualization, but without a pre-installed virtual image on the remote resource.

Under Time with delivery VI refers to the execution time of grid tasks with the necessity of transmitting VI. On the basis of this modeling and experimental results (Fig. 7), we can conclude that the relationship between task execution time in grid environment without the use of virtualization technology and using, but without the pre-installed VI on a remote computing resource significantly great. The cost of sending VI can be compensated through the development of schema replication storage virtual images and scheduling algorithm in grid environment based on the use of virtualization. The task of planning the layout of VI is under development.

Conclusion

We considered the problem of environment configuration applied to perform computational tasks in grid environment. The technology of automated environment configuration based on virtualization was proposed. The implementation is designed as an extension of the framework for the high-level grid applications development that provides an API for basic grid operations.

The results of the effectiveness evaluation of the proposed technology by conducting the experiments on the basis of the simulation model as well as in the real grid environment showed that the time required deploying the VI when starting task execution does not exceed 5% in the case of the pre-installed VI on the remote computing resource. The expenses caused by virtual image data transfer to the remote computing resource can be minimized by the development of scheme of virtual images storage replication as well as the scheduling algorithms taking into account the expenses of virtualization. This problem requires further study.

The proposed technology allows to increase the efficiency of grid environment usage, to simplify the processes of grid resources configuration, computing task designing and specification and provides the ability to use licensed software to perform calculations in grid environment.

Acknowledgments

The authors of the paper express their gratitude to Prof. Voloshyn for the invitation to participate in the conference and discussion of the results.

Bibliography

[Bivoyno, 2013] V. Kazymyr, P. Bivoyno, O. Prila, T. Guza. Methods of thread scheduling tasks in grid environment. Mathematical machines and systems, no. 4, pp. 70-82. 2013.

[Bogdanov, 2008] A. Bogdanov, E. Stankova, V. Mareev. Virtualization: New Opportunities known technology. Russian competitive selection overview and analytical articles on the priority area of "Information and telecommunication systems", p. 31. 2008. [Online]. Available: http://window.edu.ru/resource/802/58802/files/68359e2-st15.pdf.

[Buyya, 2002] R. Buyya. M. Manzur. GridSim: A Toolkit for the Modeling and Simulation of Distributed Resource Management and Scheduling for Grid Computing. The Journal of Concurrency and Computation: Practice and Experience (CCPE), vol. 14, Is. 13–15. pp. 1179 – 1219. 2002.

[Ellert, 2007] M. Ellert. Advanced Resource Connector middleware for lightweight computational Grids. M. Ellert [et al.]. Future Generation Computer Systems, vol. 23. pp. 219 – 240. 2007.

[Jain, 2012] Y. Jain. Virtualization Concepts And Applications [Online]. Available: http://www.ieee.ldrp.ac.in/index.php?option=com_phocadownload&view=category&download=2:pdf&id=1:workshop&Itemid=216.

[Kazymyr, 2013] V. Kazymyr, O. Prila, V. Rudyi. Grid workflow design and management system. International Journal “Information Technologies & Knowledge”, vol. 7, no 3. pp. 241 – 255. 2013.

[Keahey, 2005] K. Keahey, I. Foster, T. Freeman, X. Zhang, and D. Galron. Virtual Workspaces in the Grid. in Europar.. Lisbon, Portugal, 2005.

[Keahey, 2012] K. Keahey, P. Armstrong, J. Bresnahan, D. LaBissoniere, and P. Riteau. Infrastructure outsourcing in multi-cloud environment. FederatedClouds '12: Proceedings of the 2012 workshop on cloud services, federation, and the 8th OpenCirrus summit, San Jose, USA. pp. 33–38. 2012.

[Mann, 2006] A. Mann. Virtualization 101: Technologies, Benefits, and Challenges. 2006. [Online]. Available: http://www.etomicmail.com/files/dedicated_server/Virtualization%20101.pdf.

[Prila, 2014] O. Prila. The framework for high level grid applications development. Problems of programming, no 1. pp. 31–39. 2014.

[Romanova, 2011] A. Romanova. Virtualization in high-performance computing systems. Science and education: scientific publication MSTU. NE Bauman. no 3. 2011. [Online]. Available: http://technomag.edu.ru/doc/168323.html.

[Salnikov, 2015] A. Salnikov, V. Vishnevsky, A. Boretsky. "Platform as a service" in the grid for interactive analysis of medical data. Mathematical Machines and Systems , no1. pp 53 - 64. 2015.

[Volohov, 2009] V. Volohov, D. Varlamov, N Surkov, A. Pivushkov. Virtual computing environments: the use of polygons on the grid. Herald of South Ural State University. Series: Mathematical modeling and programming, no 17. pp. 24 - 35. 2009.

Authors' Information

Volodymyr Kazymyr *– Dr. Sc. Prof. Chernihiv National University of Technology, Shevchenko street, 95, Chernihiv-27, Ukraine, 14027; e-mail: vvkazymyr@gmail.com*

Major Fields of Scientific Research: Object-oriented programming, Model-based control, Simulation

Dmytro Melnychenko *– Senior Lecturer, Chernihiv National University of Technology, Shevchenko street, 95, Chernihiv-27, Ukraine, 14027; e-mail: peek@ukr.net*

Major Fields of Scientific Research: System Software, Software engineering, Enterprise systems development

Olga Prila *– PhD, Chernihiv National University of Technology, Shevchenko street, 95, Chernihiv-27, Ukraine, 14027; e-mail: olga.prila1986@gmail.com*

Major Fields of Scientific Research: Distributed computing, Simulation, Software engineering, Enterprise systems development

Mykola Kryshchenko *– Postgraduate, the assistant lecturer, Chernihiv National University of Technology, Shevchenko street, 95, Chernihiv-27, Ukraine, 14027; e-mail: mykola3451@gmail.com*

Major Fields of Scientific Research: HPC and distributed systems