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Building of Computational Grid around Virtual Enterprises

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Abstract: - Establishment of a computational grid by non-dedicated resources depends significantly on owners/users cooperation. Proposed human profiling model is targeted to increasing of resource availability. It includes parameters of human, platform, application and resource management procedure. Model parameters are collected by a web questionnaire and monitoring tools, respectively. Generated list of candidates for resource engagement increases dedication and performances of environment. Preliminary experimental results show a decrease in the application execution time and convenient communication costs. Imagined virtual organization tries to extend frames of the grid, and to ensure the flow of resources and services between research institutions and different enterprises.

Key-Words: - cluster, computational grid, cooperation, heterogeneity, human profiling, virtual enterprise.

1 Introduction

A computational grid is a set of software tools and hardware, which by using geographically distributed computers or computer clusters, enables both execution of computer intensive applications and sharing of data and resources [7]. In contrast to conventional distributed environment, similar to [12], the following holds for a computational grid: it is a virtual pool of resources, a user can access the pool but not individual nodes, access to resources may be restricted, the user has little or no knowledge about each resource, resource spans multiple trust domains, the pool can contain a great number of dynamic and heterogeneous elements.

According to [1], a virtual enterprise (VE) is a temporary alliance of companies for the lifetime of a common project, a solution for a problem, or joint production of service or a product. According to [3], the virtual enterprising paradigm considers a temporary alliance of enterprises that come together to share skills and resources in order to respond better to business opportunities and whose cooperation is supported by computer networks. Infrastructure complexity for virtual organizations (VO) is also thoroughly described in [3] and [8].

A computational grid provides significant support to scientific research. Moreover, it has also started to enter enterprises aggressively [4]. However, computer intensive applications are still in large part executed on dedicated resources. Currently, millions of high-performance computers connected by fast networks are working underloaded. Engagement of those non-dedicated resources provides numerous positive consequences [2]. By increasing the part of non-dedicated resources, heterogeneity and dynamics will definitely increase. This demands special attention by resource management [9]. By applying a corresponding mapping procedure, heterogeneity and dynamics favors execution of tasks with various requirements. Additionally, satisfactory availability of engaged non-dedicated resources depends mostly on human cooperation [10]. Human (in personal or institutional form) can be owner, user or owner/user of computational grid resources.

Computational grid establishment on non-dedicated resources corresponds to computer supported cooperative work (CSCW). According to [5] and [14], CSCW implies a group of people carrying out a certain job supported by a computer system and network technologies. The grid represents the most powerful platform, which enables a more comfortable CSCW. In contrast to that, in the worst case a human can be considered a selfish owner, i.e. a greedy resource user. Therefore, it is necessary to consider sociological, organizational, timing and other parameters of the human as the resource owner/user, as in [11].

By connecting the provider with a user of services, a new form of VO is always formed [5]. Ownership of a considerable part of non-dedicated resources, the will and/or interest in its concession, as well as the need for high computing power are the main initiators of establishing not only enterprise grids, but also global grid organizations

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[8]. Such organizations very often include research institutions working with data intensive, but often off-line applications. More often they will include virtual plants demanding very short responses, which cannot be acquired by using their own computer resources. According to [3], the paradigm of virtual enterprising challenges the way manufacturing systems are planned and managed.

With respect to the necessity of cooperation in grid extension by non-dedicated resources, Section 2 deals with the procedure of determining the human profile. Section 3 shows the human-centric model whose parameters are collected by a questionnaire and measurement procedure. Section 4 describes building of a computational grid by engaging non-dedicated resources around a cluster. The proposed approach is evaluated in simplified environment in Section 5. The obtained results represent a strong motive for further research, which is also expressed in Conclusion.

2 Human in Computational Grid

2.1 Human Behavior

A grid will surely offer to human enormous possibilities pertaining to providing solutions to computer intensive problems. At the same time, human represents 'the weakest link' of such VO, as in [11]. In the worst case, we have a selfish resource owner and a greedy service user. In order to set equality of all users, the resource management system is successful in preventing greedy uses, but it is almost helpless in case of selfish resource ownership. This particularly refers to the owner, since he does not require any grid services. For a sufficient large number of owners willing to concede resources this problem is mostly solvable. However, non-cooperativeness of owners in grid establishment of non-dedicated resources can significantly reduce environment performances. Whether it is owner/user, motives for cooperation are not lacking, since by conceding resources he is entitled to the right of using grid services free of charge. Fortunately, most often the largest resource owners are at the same time great service users. However, that fact restricts grid establishment to confined space of dedicated resources (scientific institutions and large enterprises).

A great deal of non-dedicated resources in a grid enables greater computer power for less money, but also flexibility and reliability relating to execution of computer intensive applications. Finally, profit can be not only of financial, but also of ecological and sociological nature as in [10].

2.2 Profile Determination

According to [6], involvement of non-dedicated resources into a grid is a problem of mutual cooperation between resource owners, i.e. owner/user. By increasing the part of non-dedicated resources, virtuality of environment increases as well. These are the main reasons for the procedure of human profile determination shown in Table 1.

Table 1. Human profile determination

<table>
<tr><th colspan="6">Human Profile Determination</th></tr>
<tr><td colspan="6">Security and privacy guaranteed!</td></tr>
<tr><td colspan="3">Engagement of resources in computational grid?</td><td colspan="3">Computational grid services usage?</td></tr>
<tr><td colspan="2">Owner</td><td colspan="2">Owner/user</td><td colspan="2">User</td></tr>
<tr><td colspan="6">Authorization</td></tr>
<tr><td colspan="6">Lists of parameters</td></tr>
<tr><td colspan="3">Manual</td><td colspan="3">Automatic</td></tr>
<tr><td colspan="2">Ω</td><td colspan="2">Ω</td><td colspan="2">Ω</td></tr>
<tr><td colspan="2">P</td><td colspan="2">P</td><td colspan="2">-</td></tr>
<tr><td colspan="2">-</td><td colspan="2">A</td><td colspan="2">A</td></tr>
<tr><td colspan="2">-</td><td colspan="2">M</td><td colspan="2">M</td></tr>
<tr><td colspan="6">Static parameters acquisition and saving to database</td></tr>
<tr><td colspan="4">Performance evaluation</td><td colspan="2">Rating calculation</td></tr>
<tr><td colspan="6">Initial (static) priority list</td></tr>
<tr><td colspan="6">Application execution</td></tr>
<tr><td colspan="6">Dynamic parameters acquisition and saving to database</td></tr>
<tr><td colspan="4">Dynamic performance evaluation</td><td colspan="2">Environment observation</td></tr>
<tr><td colspan="6">Dynamic priority list</td></tr>
<tr><td colspan="6">Application execution</td></tr>
</table>

The procedure guarantees entire security and privacy. It is carried out by a web questionnaire (manually) as well as measurement of environment parameters (automatic). A great majority of static parameters is collected by a web questionnaire. On the other hand, one part of static and all dynamic parameters are collected by software tools. The sequence of procedure execution, i.e. a parameter list, depends on human identification as owner, owner/user or user. Similar to [10], environment parameters are classified into four groups: human (Ω), platform (P), application (A), and mapping procedure (M). Parameters of level Ω are important for all three profiles. Level P is important for owner and owner/user, level A for owner/user and user, whereas level M is important for owner/user and user.

Generally, static parameters enable initial evaluation and calculation of rating by concession or usage of resources. Dynamic parameters enable constant observation of changes in environment at all four levels, as well as replacement of bad resources by better ones. Briefly, this procedure increases dedication of environment. Parameters are described in the next section.

3 Human Profiling Model

3.1 Parameters Collected by Questionnaire

Human parameters are shown by (1).

$$\Omega_q = \{O(inh, hi, I, inst-p/f), UO, KE, a_{ex}, E, \Pi\}, \quad (1)$$

where

O - ownership of resources. Resources can be inherited (inh), hired (hi) or personal (I). The owner can also be an institution, partially ($inst-p$) or fully ($inst-f$) authorized to manage resources.

UO - possibility of human transition from the status of user to the status of owner/user.

KE - human knowledge and experience level in grid technology. It depends on the educational degree humans and their past activities in the same or similar area.

a_{ex} - expected availability of owner/user for additional interventions in the system work (e.g. engagement of additional resources).

E - expected efficiency of owner or owner/user, e.g. announced and accepted ratio of given and taken services.

Π - announced intention to increase resource performances (new machines, system software or some parameters from the level P).

Platform parameters included in the web questionnaire are shown by (2).

$$P_q = \{OS_P, CPU(f,n), MEM, NET, HDD, CG_{spt}, \overline{U}\}, \quad (2)$$

where

OS_P - platform operating system.

$CPU(f,n)$ - CPU clock frequency and number of processors in machine.

MEM, NET, HDD - available RAM, nominal network speed and hard disk space.

CG_{spt} - software support for cluster or grid environments.

$\overline{U}$ - empirical estimation of machine workload (also ranging from 1 to 5).

Expression (3) shows parameters of application.

$$A_q = \{OS_A, pmtn_A, m_A, size_A, pr_A, data(l, cons), c_{ex}\}, \quad (3)$$

where

OS_A - required operating system. Most often applications can be independent of the platform and the operating system.

$pmtn_A$ - application preemptability.

m_A - desired number of engaged machines.

$size_A$ - size of execution code of application (including or excluding data space).

pr_A - desired priority level.

$data(l, cons)$ - location and consistency of data location.

c_{ex} - expected execution time.

Mapping parameters included in the web questionnaire are given in (4).

$$M_q = \{\gamma(c_{\min}^{\max}, LB), pmtn_M, reM, l_M, \Theta_M(S, D, SD)\}, \quad (4)$$

where

$\gamma(c_{\min}^{\max}, LB)$ - objective function (minimal or total expected execution time, load balancing etc.).

$pmtn_M$ - possibility of mapping preemption.

reM - possibility of remapping.

l_M - location of mapping execution (mapping can be either centralized or decentralized).

$\Theta_M(S, D, SD)$ - timing characterization of mapping execution (mapping can be either static, dynamic or combined).

3.2 Measured Parameters

Measured parameters of human are shown by (5).

$$\Omega_m = \{o, ou, ke, a(t, patt), e, cr, recr, \pi\}, \quad (5)$$

where

o - resource ownership changes.

ou - observed announcement of status change from user to owner/user.

ke - grid technology knowledge and experience level changes.

$a(t, patt)$ - availability (in hours) or availability pattern (daily, weekly, monthly).

e - achieved efficiency of owner or owner/user. It is the ratio of the measured time in which the testing application is finished on engaged resources and the time in which this application is executable on the grid.

cr - credit of owner or owner/user, debt of user. By inconvenient efficiency e, owners/users can also have debt (costs).

$recr$ - recruitment of new owners or owners/users. This is rewarded additionally.

π - achieved increase in resource performances. It is determined as the ratio of the testing application execution times before and after a registered or observed change of ownership or changes at level P.

Dynamic platform parameters are included in expression (6).

$$P_m = \{a_m(t, patt), cpu, mem, net, hdd\}, \tag{6}$$

where

$a_m(t, patt)$ - machine availability on the network (in each observed instant t and according to availability pattern $patt$).

cpu, mem, net, hdd - unused capacity of processor or RAM, real speed of network and free storage (disk) space.

Application parameters given by monitor programs are shown in (7).

$$A_m = \{c, c_{re}, t_{setup}\}, \tag{7}$$

where

c - achieved execution time

c_{re} - remaining execution time.

t_{setup} - setup time.

Expression (8) contains dynamic parameters of mapping.

$$M_m = \{c_M, n_{reM}, rank_\gamma\}, \tag{8}$$

where

c_M - mapping time.

n_{reM} - number of remappings.

$rank_\gamma$ - rank of used algorithms.

4 Building of Grid

The proposed grid should be built around clusters. A dedicated part of resources consists of clusters located at our institutions. Clusters have a different number of nodes and each node has 4 machines. In addition to the operating system (RedHat Enterprise Linux 3.0), cluster distribution NPACI Rocks, described in [13], contains middleware (enables the job management system), cluster monitoring tools, parallel execution libraries, cluster management tools, and global process space. Available non-dedicated resources are for the time being mostly situated within the academic environment. However, resources of other institutions and enterprises are planned to be engaged, especially the ones interested in the usage of grid services. Users of grid services are currently university departments and institutes, clinical hospital, and the nearby factory implementing the grid in the quality control of its products.

The job management system creates a job queue sent to the application server outside the cluster. In real applications, this remapping would take place when the total cluster workload and/or workload of a single machine in the cluster were observed to be greater than the threshold of critical workload (usually greater than 0.75). In contrast to that, one application simulates workload and always puts the cluster workload close to the threshold, so that in the last two experiments non-dedicated machines are always used.

A list of machines candidates for mapping is made on the basis of a questionnaire run on the application server outside the cluster. During application execution, some parameters of the model described in Section 3.2 are collected. A certain number of machines of the highest performance are assigned jobs and credits, i.e. costs are calculated in the case of a user.

5 Preliminary Experiment

5.1 Experimental Setup

A preliminary experiment has been carried out in a simplified environment: one institution, a three-node cluster with 12 machines (P IV 2.8GHz, 512MB RAM etc.) accessible at grozd.etfos.cro-grid.hr, two groups with 20 non-dedicated machines each (P IV 2.4 GHz, 512MB RAM or similar), 100Mb/s LAN.

One administrator has 8 non-dedicated machines at his disposal, whereas individual users manage the remaining 12 ones. A testing application is a part of the image processing application, which carries out multiplication of a quadratic matrix of dimensions 5000x5000. According to a simple algorithm BS (Best Subset) from [11], out of 20 machines from the group, 15 best machines try to join job execution. On the basis of collected data during application execution, bad machines are eliminated from such a grid and replaced by some better ones.

Evaluation is done from the application viewpoint in accordance with two parameters described in [11]. In various environments and conditions, the application execution time (c) indicates improvement of the system throughput. The ratio of communication costs and execution time (com/c) indicates network workload in dependency of environment extension.

5.2 Results

Experiment 1 shows the testing application execution time on a non-dedicated machine. Experiment 2 implies application execution exclusively on the cluster. In Experiment 3 non-dedicated machines, which were granted authorization necessary for their participation in the grid, are also assigned to the cluster. Thereby their owners do not fill in the questionnaire and do not have any monitoring tool installed either. In Experiment 4, all owners fill in the questionnaire and install the monitoring tool. Table 2 and Figure 1 show results obtained by executing testing application in conditions described by experiments.

Table 2. Experimental results

Evaluation parameter		Exp. 1	Exp. 2	Exp. 3	Exp. 4
c	min	20.85	1.38	1.01	0.71
	sec	1251	83	61	43
com/c		-	1	1.41	1.29

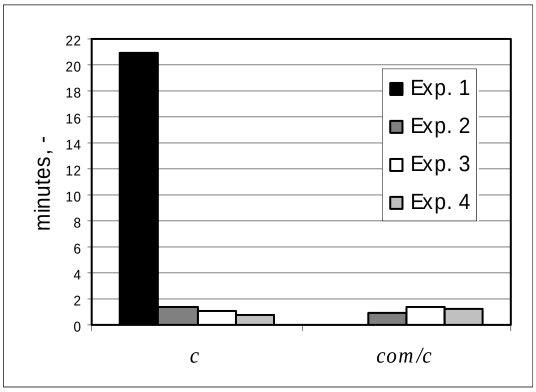

Figure 1. Comparison of experimental results

On the non-dedicated machine, testing application is executed in approx. 21 minutes (Exp. 1), while on a three-node cluster (12 machines), it is about 83 seconds (Exp. 2). In Exp. 3, out of 20 machines, 15 machines try to join in. This is not successful for all machines without parameter collection. In that way, c decreases to about 1 minute. Also, by engaging non-dedicated resources com/c increases by 41% compared to Exp. 2. As late as Exp. 4, c is decreased to about 43 seconds, i.e. it is reduced by 29% in comparison with the case without human and environment profiling. In contrast to Exp. 3, in Exp. 4, ratio com/c decreases. That means that the questionnaire and monitoring tools increase availability. In other words, the number of assigned machines of low performance and availability is reduced.

6 Conclusion

A computational cluster significantly speeds up execution of computer intensive applications. Inclusion of such dedicated resources into the grid enables enormous power and proportionally guaranteed computer power. Such solution is expensive and does not include non-dedicated resources, i.e. a large number of powerful underloaded machines connected by fast networks. Availability of these resources depends primarily on human as owner or owner/user.

The proposed model of human and their resources profiling puts resource owners/users into a competitive position. The model motivates them for cooperation on the level of platform, application and resource management. Model parameters are collected by a web questionnaire and monitoring tools. In fact, it is the collection of static and dynamic environment parameters that is responsible for almost twice shorter execution time and a significant reduction of communication costs. Without the previously described approach an inclusion of non-dedicated resources into the grid would not attain the desired execution time, and it would considerably increase communication costs.

By including a larger number of non-dedicated machines, execution time can be shorter than a second without any problems. Such environment performances are interesting to research institutions, factories and other enterprises, which is an important motive for further research directed towards creating a virtual organization. It should provide an exchange of computer resources and services outside the research community as well.

References:

[1] N.A. Assimakopoulos, A.D. Theodosi, A Systematic Approach for Modeling Virtual Enterprise's Management Features, *Tamkang Journal of Science and Engineering,* Vol.*6,* No.2, 2003, pp. 87-101.

[2] G. Beenen, K. Ling, X. Wang, K. Chang, D. Frankowski, P. Resnick, R.E. Kraut, Using Social Psychology to Motivate Contributions to Online Communities, *Proc. of 2004 ACM Conf. on Computer Supported Cooperative Work (CHI '04),* Chicago, IL, Nov. 6-10, 2004, ACM Press, New York, NY, 2004, pp. 212-221.

[3] L.M. Camarinha-Matos, New Collaborative Organizations and their Research Needs, *Proc. of IFIP 5th Working Conf. on Virtual Enterprises (PRO-VE '03),* Lugano, Switzerland, Oct. 29-31, 2003, Kluwer, Norwell, MA, 2003, pp. 3-14.

[4] J.S. Chase, D.E. Irwin, L.E. Grit, J.D. Moore, S.E. Sprenkle, Dynamic Virtual Clusters in a Grid Site Manager, *Proc. of 12th IEEE Int. Symp. on High Performance Distributed Computing (HPDC '03),* Seattle, WA, June 22-24, 2003, IEEE Press, New York, NY, 2003, pp. 90-100.

[5] G. Chung, P. Dewan, Towards Dynamic Collaboration Architectures, *Proc. of 2004 ACM Conference on Computer Supported Cooperative Work (CSCW '04),* Chicago, IL, Nov. 6-10, 2004, ACM Press, New York, NY, 2004, pp. 1-10.

[6] A. Corsaro, A. Di Stefano, G. Pappalardo, C. Santoro, E. Tramontana, Emerging Technologies for Next-generation GRID, *Proc. of 13th IEEE International Workshops on Enabling Technologies (WETICE '04),* Modena, Italy, June 14-16, 2004, IEEE Press, New York, NY, 2004, pp. 243-246.

[7] I. Foster, C. Kesselman, S. Tuecke, The Anatomy of the Grid: Enabling Scalable Virtual Organization. *Int. Journal of High Performance Computer Applications,* Vol.15, No.3, 2001, pp. 200-222.

[8] J. Fraga, R.J. Rabelo, F. Siqueira, C.B. Montez, R.S. Oliveira, Infrastructure for Virtual Enterprises in Large-Scale Open Systems, *Proc. of 8th IEEE International Workshop on Object-Oriented Real-Time Dependable Systems (WORDS'03),* Guadalajara, Mexico, Jan. 15-17, 2003, IEEE Press, New York, 2003, pp. 242-249.

[9] M. Maheswaran, S. Ali, A Taxonomy of Network Computing Systems, *IEEE Computer,* Oct. 2004, pp. 115-117.

[10]G. Martinovic, Owner/User Role in Computational Grid Extension by Non-dedicated Resources. *Proc. of ACM Int. Symp. on Supporting Group Work, (GROUP '03),* Sanibel Island, FL, Nov. 9-12, 2003, ACM Press, New York, NY, 2004, 221-228.

[11]G. Martinovic, L. Budin, Human in Computational Grid Establishment, *Proc. of IEEE Int. Conf. on Systems, Man & Cybernetics (SMC '04),* The Hague, The Netherlands, Oct. 10-13, 2004, Omnipress, Piscataway, NJ, 2004, pp. 88-93.

[12]Z. Nemeth, S. Sunderam, Characterizing Grids: Attributes, Definitions, and Formalisms, *Kluwer Journal of Grid Computing,* Vol.1, No.1, 2003, pp. 9-23.

[13]NPACI Rocks, www.rocksclusters.org.

[14]C. Simone, M. Sarini, Adaptability of Classification Schemes in Cooperation: What Does It Mean?, *Proc. of 7th European Conf. on Computer Supported Cooperative Work (ECSCW '01),* Berlin, Germany, Sept. 16-20, 2001, Kluwer, Norwell, MA, 2001, pp. 19-38.