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Self-adaptivity for grid applications. An Efficient Resources Selection model based on evolutionary computation algorithms

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ABSTRACT

Over the last few years, the adaptation ability has become an essential characteristic for grid applications due to the fact that it allows applications to face the dynamic and changing nature of grid systems. This adaptive capability is applied within different grid processes such as resource monitoring, resource discovery, or resource selection. In this regard, the present approach provides a self-adaptive ability to grid applications, focusing on enhancing the resources selection process. This contribution proposes an Efficient Resources Selection model to determine the resources that best fit the application requirements. Hence, the model guides applications during their execution without modifying or controlling grid resources. Within the evaluation phase, the experiments were carried out in a real European grid infrastructure. Finally, the results show that not only a self-adaptive ability is provided by the model but also a reduction in the applications' execution time and an improvement in the successfully completed tasks rate are accomplished.

1. Introduction

Grid computing is an innovative distributed paradigm proposed by Foster and Kesselman [1,2] in 90s. It was introduced as a revolutionary technique for solving massive computational problems by sharing computational power and storage capacities. The term emerges from the analogy with the electric power grids: users connect to a grid computing infrastructure and get computing power without knowing where it comes from, like the electrical power they get at home.

Several organizations and research centres are involved within a grid infrastructure by sharing their resources. These resources have different geographical locations and are grouped into Virtual Organizations (*VO*). Every *VO* refers to a set of institutions with a common goal. Furthermore, each *VO* has been associated with a particular research project. It should be highlighted that the number of resources can be increased according to the project requirements (this kind of infrastructure provides unlimited storage and computing power).

Despite the advantages of grid computing systems, there are several problems related to task management, resource discovery, resource monitoring, and resource selection. As mentioned, different centres with different administrative domains handle grid resources. This fact leads to a dynamic and changing environment: the characteristics, availability and performance of grid resources vary over time. Moreover, applications face a double heterogeneity within these infrastructures: on the one hand, grid environments are composed of heterogeneous resources (with heterogeneous hardware and software

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characteristics). On the other hand, there are heterogeneous resources with the same grid functionality. In addition, grid applications compete for using these non-dedicated resources. Regarding the monitoring, discovery and selection processes, the system ideally needs to know the infrastructure status in real-time for registering updated information within the *Information System* (*IS*).

For addressing these problems the *adaptation* concept is introduced as a feasible solution in grid community. This idea arises from two main issues: first, applications require real-time information about the environment for dealing with grid changing conditions. Second, the system continually requires updated information about resources (their status and availability) in order to make decisions autonomously. In recent years, several solutions based on the *adaptation* concept have been proposed. However, applying adaptation at any grid level has become a challenging topic because of the behaviour and principles of such infrastructure.

The present contribution is focused on enhancing the grid resources selection process by determining the resource set that best fit the application requirements. For that reason, it provides a self-adaptive capability to grid applications, selecting at every time the most efficient resources. The model has been designed from the user point of view without modifying the behaviour or the characteristics of grid resources. Concerning tasks, they are progressively executed (not all at once due to the fact that the model does not duplicate tasks) for profiling the resources' efficiency during the application's execution. This way, the model learns about the infrastructure's status and a suitable use of grid components is performed (considering an appropriate usage of resources without monopolizing them; grid elements can be exploited by several users at the same time). A mathematical formulation (Section 3.2) is defined for measuring resources' efficiency. This formulation is combined with an Evolutionary Algorithm (*EA*) for obtaining an efficient selection process. Specifically, the following algorithms have been combined with the proposed mathematical formulation, resulting in four versions of the model: the Variable Neighbourhood Search (*VNS*) metaheuristic [3,4], a Cellular Automata (*CA*) methodology [5] and the Preferential Attachment (*PA*) technique [6,7] from the Complex Network field. Moreover, in this contribution we present an enhanced version of the model based on the Scatter Search (*SS*) [8–10]. From now on, we denote our approach as *Efficient Resources Selection* Model (*ERS*) [11,12] and the different versions are called respectively *ERS-SS*, *ERS-VNS*, *ERS-CA* and *ERS-PA*.

The rest of the paper is structured as follows. In Section 2 a discussion about related works is presented. Section 3 introduces the problem, by describing the model assumptions and the proposed mathematical formulation. The *ERS-SS* is described in Section 4. Section 5 summarizes the previous *ERS* versions. The evaluation of the model, including the resulting experimental data, is discussed in Section 6. This evaluation has been performed in a real European grid infrastructure. Finally, Section 7 concludes the paper.

2. Related work

There are several researches focused on solving grid infrastructure problems by applying self-adaptation. In some cases, an adaptive system for dealing with the environmental changes is proposed (an autonomous system). In other studies, intelligent frameworks are developed for providing an efficient jobs scheduling. Finally, there are solutions that apply *adaptation* in specific grid processes (discovery, monitoring, selection, etc.).

In [13] an alternative to solve the problem of resources selection is proposed. First, the application execution starts on any resource set. Then, certain information about communication and processing times is collected periodically. With these metrics two efficiency thresholds (lower and upper thresholds) are determined. The objective is to keep the application's efficiency between these values. Resources are added or deleted based on these premises. Certain migration techniques are also applied.

Authors in work [14] propose an approach for enhancing grid infrastructures by avoiding jobs restrictions. This way, they provide an adaptive capability to applications. For that reason, the contribution describes three options to overcome those restrictions: first, an approach which implies a change on the infrastructure's design. Second, a solution in which a flexible job management is developed. Finally, a strategy focuses on fostering the cooperation between users and infrastructure.

Also the concept of *living application* emerges in grid community for solving the problems mentioned above. In this regard, the work in [15] presents a methodology for managing grid applications in an autonomous way. The methodology is based on the following principles: the application makes decisions about which tasks to do and which resources to use (these decisions are based on runtime knowledge). Thus, the application decides in an autonomous way when performing a task migration (the application requires administrative privileges).

Grid environments are increasingly used for performing long running multi-phase parallel applications. This fact has motivated the authors in [16] for developing an efficient rescheduling framework, by allowing applications to adapt to the dynamic environment. Three strategies have been designed to decide when and where to reschedule this type of grid parallel application. A similar approach is presented in [17] for long running multi-physics coupled parallel applications.

The Advanced Resource Connector (*ACR*) grid middleware was designed and proposed several years ago, resulting in an interesting solution for adapting this layer to new data management and storage. The version described in contribution [18] aims to solve certain problems detected in *ACR*, like system bottleneck fails. The new approach includes a layered structure (in particular 3 layers), which efficiently uses the available bandwidth as well as enables data transfer slots based on a priority system.

The research in [19] describes a migration framework in which new scheduling policies are included. In this framework, both the resources' load and the application characteristics are considered. Therefore, the novel policies are used for varying