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A survey of economic models in grid computing

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ABSTRACT

Grid computing offers the network of large scale computing resources. Economic models are effective in collaborating large scale heterogeneous grid resources that are typically owned by different organizations. Not all the models provide same benefits for users in utilizing the resources. Similarly, the profit earned by resource providers also differs for different economic models. We survey the economic models used in grid computing since its inception until 2010. We discuss their advantages and disadvantages and analyze their suitability for usage in a dynamic grid environment. To the best of our knowledge, no such survey has been conducted in the literature up to now.

1. Introduction

Investigation of some problems in science, engineering and commerce such as protein analysis, material properties, and economic forecasting are computationally complex. By realizing the insufficiency of a single computer, a cluster or even a supercomputer in solving these problems, grid computing was initiated in the mid 1990s [1]. The technology that aggregates distributed computer resources across the world is called grid computing. Coordination of distributed and heterogeneous computing resources creates virtual organizations that support the utilization of idle resources [2]. However, seamless collaboration is a challenge due to the extreme heterogeneity of these resources. This heterogeneity is due to varying architectures architecture of physical resources (e.g. clusters, supercomputers, ordinary PCs), different administrative domains (e.g. country, enterprize) and multiple operating systems (e.g. UNIX variants, Windows). There is also a lack of a uniform way to use these resources.

Fig. 1 shows layers and different components that constitute a typical grid. The layered grid architecture usually rests on the *fabric layer* that consists of servers, clusters, monitors and all other distributed computing resources around the world. Mercury [3] system is a good example for this layer. The layer that controls and allows secure access to the components of fabric layer is called the *core middleware layer*. It also supports

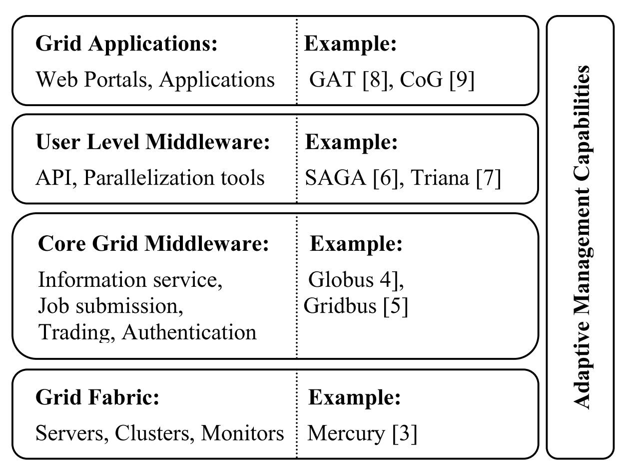

Fig. 1. Layered grid architecture with examples.

trading and information updating of resources. Globus [4] is a well-known middleware service, which allows resource discovery, management and security. On the other hand, Gridbus [5] middleware supports business driven technologies aimed at utility based computing. Gridbus uses economic models that aid efficient management of shared resources through maintaining the supply and demand of distributed resources. In this paper, we focus on suitable economic models in grid computing and their practicality of usage in different perspectives. The upper level of core grid middleware is called *user level middleware* that provides API (Application Programming Interface), libraries, application development environments and resource mediator,

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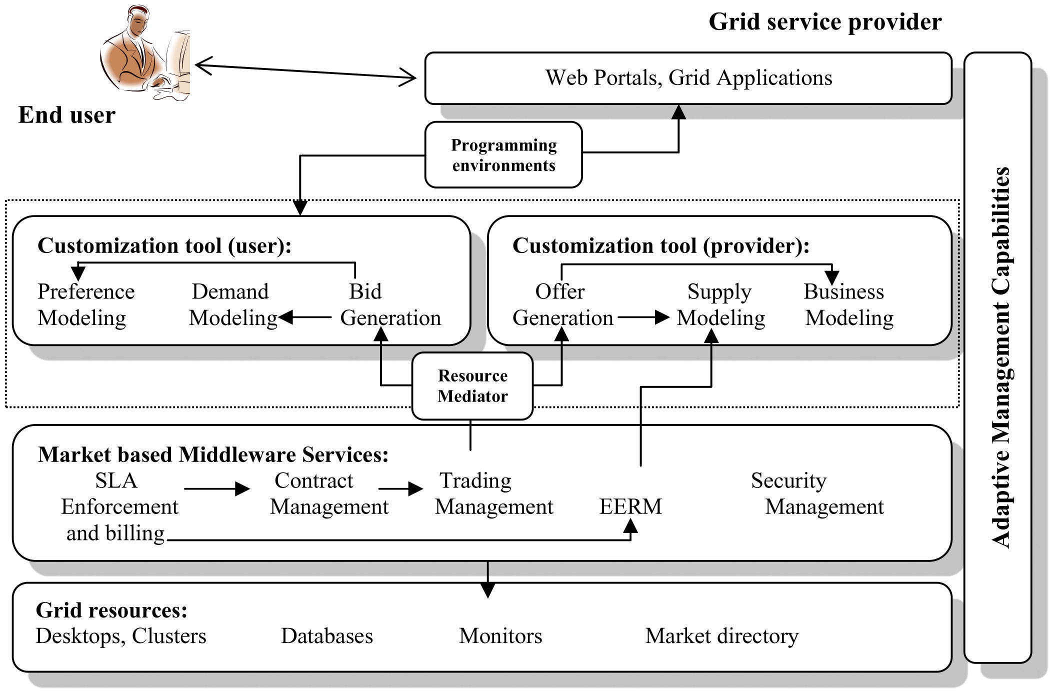

Fig. 2. A reference Market oriented overview of a layered Grid architecture [2].

which negotiates between users and providers, and schedules application tasks for execution on global resources. The Simple API Grid Applications (SAGA) [6] and Triana [7] are the two examples of user level middleware. This middleware is used to communicate with the core middleware. *Grid applications*, the fourth layer, is typically developed using the components of user level middleware. This layer supports users to execute their applications on remote resources and collect results from them using web portals or applications such as the Grid Application Toolkit (GAT) [8] and java Commodity Grid kit (CoG) [9].

The core part of the grid is called core grid middleware, since it offers all the necessary functions such as scheduling, security, data transfer, trading and communication [10]. The main objective of this middleware is to hide the heterogeneous nature and provide a homogeneous and flexible environment to end users. Trading is one of the main parts that motivates resource providers to contribute their resources on grid computing. In addition, price is a key deciding factor in resource use [11]. Price can further be used to maintain equilibrium between supply and demand, distinguish different QoS (Quality of Service) requirements and utilize idle resources. A market oriented modeling can be used in solving distributed resource management problems such as site autonomy problem, objective optimization problem and cost management problem [12]. The site autonomy problem could occur while accessing resources that belong to different administrative domains. The objective optimization problem occurs when users want to optimize their QoS and when providers want to maximize their profit. Grid resource providers need to support seamless management of different requests from different users simultaneously—this known as the cost management problem. Several economic models are proposed in the literature for driving market-oriented grid computing. One economic model is different from the others in pricing resources for varying scenarios.

In this article, we investigate suitable economic models for grid computing. The analysis covers models that have been proposed since the inception of grid computing and discusses their strengths and weaknesses as perceived by researchers. Finally, we identify that different models are suitable for dealing with different grid scenarios; however we find no work considering multiple economic models and switching between them for varying scenarios in a grid environment.

The remainder of this article is organized as follows: In Section 2, we explore market oriented grid computing. Section 3 explains the strengths and weaknesses of different economic models that have been proposed and used by different grid computing researchers thus far. Section 4 maps out some future research directions in market oriented grid based on the analyses of the models.

2. Market oriented grid computing

Standardization, usability and business models have been accepted as the main success factors for next generation computing systems [13]. However, market based computing mechanisms are different from the traditional mechanisms in terms of value (i.e. QoS) delivered to a user. The value could be measured by the following:

- flexibility in parameterization of user driven jobs,
- suitability of business models for different user requirements and strategies and
- adaptation to changes in resource availability, capability and pricing.

To realize this, market oriented computing organizations need to be more complex than the traditional systems.

Fig. 2 presents the four grid layers of Fig. 1 in terms of market oriented modeling environment. Each layer has some additional functional entities along with dependencies among them. The arrow from A to B refers to the dependency of A on B. In a market oriented architecture, market directory service keeps the resource information updated and helps to generate a competitive market price for a particular type of resource. Market based middleware supports market participants to trade grid resources. It performs trading activities such as SLA (Service Level Agreement) enforcement and billing, contract and trading management. All