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Kurt Vanmechelen
Jörn Altmann
Omer F. Rana (Eds.)

# Economics of Grids, Clouds, Systems, and Services

8th International Workshop, GECON 2011
Paphos, Cyprus, December 2011
Revised Selected Papers

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Volume Editors

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# Lecture Notes in Computer Science 7150

*Commenced Publication in 1973*
Founding and Former Series Editors:
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# Preface

You are holding the proceedings of the 8th International Workshop on the Economics of Grids, Clouds, Systems, and Services. This workshop brings together the research and practitioner communities active in the area of economics and computer science to address the emerging interest in infrastructure, platform, and software services. This includes the operation and structure of the service market, the alignment of cost, revenue, and quality-related objectives, and the creation of innovative business models and value chains.

This year again we received a number of high-quality paper submissions. Each submission was reviewed at least three times by an international Program Committee. Our final program consisted of five highly interactive and thought-provoking sessions (two of which were work-in-progress sessions):

- Session A: Market Mechanisms and Negotiation
- Session B: Cost Models, Charging, and Trading Platforms
- Session C: Resource Allocation, Scheduling, and Admission Control
- Session D: Work in Progress: Risk Assessment and Economics of Cloud Services
- Session E: Work in Progress: Cost-Aware Adoption of Cloud Services

As the five session titles suggest, the workshop brings together contributions from economics, resource allocation, resource management, and risk assessment. In total, there were 14 contributions (consisting of nine full papers and five work-in-progress papers) selected from 27 submitted papers. The acceptance rate of full papers is 33%.

The first paper in Session A by Haque et al. entitled "An Inspiration for Solving Grid Resource Management Problem Using Multiple Economic Models" compares a number of currently used economic models in grid computing, such as commodity markets, continuous double auctions, English auctions, contract-net protocols, and bargaining, in order to identify the settings in which one economic model out performs another. A quantitative experimental evaluation is undertaken to support this comparison—in particular to identify when to switch between such models and when to use a combination of them. The contribution "Concurrent Negotiations in Cloud-Based Systems" by Siebenhaar et al. addresses the lack of quality-of-service guarantees available within existing cloud systems. It proposes an automated negotiation approach that considers both the individual business objectives and strategies of the negotiation partners along with the dependencies between the different services and service tiers within a cloud system. The last contribution in this session from Roovers et al. entitled "A Reverse Auction-Based Market for IaaS Cloud Resources" investigates the creation of an open market for IaaS resources and proposes a continuous reverse auction along with a bidding language. It thereby specifically takes into account the current pricing schemes of real-world cloud resource providers.

# Organization

GECON 2011 was organized by the Technology Management, Economics, and Policy Program, Seoul National University, the School of Computer Science, Cardiff University, and the University of Antwerp in collaboration with ICSOC 2011.

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Session B starts with a paper by Mohammad Mahdi Kashef and Jörn Altmann entitled "A Cost Model for Running Hybrid Clouds," which identifies a usage-based cost model for running a cloud environment consisting of both public and private (data center based) clouds. The author argues that although cloud computing promises to reduce the cost of IT through lower capital and operational expenses, providing a clear specification of these costs is often lacking in the existing literature. The subsequent contribution by Stefanov et al. entitled "How to Do Successful Chargeback for Cloud Services" utilizes experience of field experts from IBM. It provides factors that identify how to allocate IT service costs to business users based on their service consumption and how to facilitate the transition to a cloud environment. The authors argue that it is often difficult to pinpoint the actual costs incurred through service provisioning and address this limitation in their work. The final contribution in this session from Menychtas et al. entitled "A Marketplace Framework for Trading Cloud-Based Services" proposes a cloud marketplace platform for the development and trading of XaaS products. It provides a single point of access for consumers interested in services and provides specialist support for sellers wishing to make their services available through the platform.

Session C starts with a contribution from Macias and Guitart entitled "Client Classification Policies for SLA Negotiation and Allocation in Shared Cloud Datacenters," focusing on how user types (internal vs. external, preferential vs. standard) could be used by providers during SLA negotiations. Experiments are used to compare two such negotiation strategies: price discrimination and client-aware overselling of resources. In their paper "Budget-Deadline Constrained Workflow Planning for Admission Control in Market-Oriented Environments," Zheng and Sakellariou focus on workflow planning and execution, taking into account the deadline and budget constraints of users submitting workflows. The proposed heuristic also takes account of the existing load on the resources that must enact the workflow. Finally, Li et al. in their paper entitled "Virtual Machine Placement for Predictable and Time-Constrained Peak Loads" discuss how virtual machines should be placed on servers within a data center in order to deal with peaks in workload and make the execution time of tasks more predictable. They discuss the trade-off between computation time and the quality of solutions provided by a binary integer program and three approximations that increase the scale at which this NP complete problem can be solved.

The final two sessions constitute the "Work-In-Progress" papers—primarily focusing on work that is at an early stage of maturity, but likely to make significant contributions to the community. The first of these, Session D, focuses on risk assessment and economic models associated with cloud service provision. Petri et al. in their contribution "Risk Assessment in Service Provider Communities" discuss the notion of financial risk from the perspective of various stakeholders involved in cloud-based service provisioning. Künsemöller and Karl in their paper entitled "A Game-Theoretical Approach to the Benefits of Cloud Computing" identify characteristics of beneficiaries in an infrastructure-as-a-service market and the potential actions they could take to gain financial benefit.

Session E includes three contributions focusing on cost efficiency. The paper by Sengupta and Annervaz entitled "Planning for Optimal Multi-Site Data Placement for Disaster Recovery" discusses strategies for backup of critical business data across (a large number of) multiple data centers (in different geographical locations). The approach takes into account criteria such as cost of storage and network, protection level against site failures, as well as business and operational parameters such as recovery point and time objectives. Their approach uses data-encoding techniques that can facilitate recovery from multiple data center failures. Shi et al. in their contribution "Saga: A Cost-Efficient File System Based on Cloud Storage Service" describe a cost-efficient file system that provides a POSIX interface on top of Amazon S3. Cost reduction is achieved by minimizing the storage space used through "store-one-copy" and "copy-on-write" strategies and by minimizing the number of requests through a distinction of objects loaded by write and read requests in the cache replacement algorithm. The final contribution of this session from Stephen McGough entitled "Developing a Cost-Effective Virtual Cluster on the Cloud" discusses how an entire cluster computing environment could be run on a cloud system, taking into account various usage policies and execution costs.

We would like to thank the reviewers and Program Committee members for completing their reviews on time, and giving useful and valuable feedback to the authors. We would also like to extend our thanks to the organizers of ICSOC for hosting our workshop alongside their conference this year. Furthermore, we would like to express our gratitude toward Alfred Hofmann from Springer for his support in publishing the proceedings of GECON 2011.

December 2011

Kurt Vanmechelen
Jörn Altmann
Omer F. Rana

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## Session B: Cost Models, Charging, and Trading Platforms



## Session C: Resource Allocation, Scheduling, and Admission Control

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## Session E: Work in Progress: Cost-Aware Adoption of Cloud Services

# An Inspiration for Solving Grid Resource Management Problems Using Multiple Economic Models

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**Abstract.** Economic models can motivate resource providers to share resources across multiple administrations in Grid computing. Our survey on existing economic models in Grid computing identified that different economic models are suitable for different scenarios. In this paper, we conduct an experiment to quantify the strengths and weaknesses of widely proposed economic models in the Grid - Commodity Market, Continuous Double Auction, English Auction, Contract-Net-Protocol and Bargaining. Based on this experimental analysis, we identify regions where a particular economic model outperforms others. Then, we indicate that switching between the economic models could be used to maximize benefits in a specific scenario.

**Keywords:** Domain of strength, economic models, Grid, optimization.

## 1 Introduction

Grid computing harnesses computational resources across geographical boundaries. The aim of this computing framework is to solve some complex problems, such as drug design in a more cost effective and standard way. Due to multiple boundaries, the problem solving through coordinated distributed environment becomes challenging. Extensive research has been conducted and it has been identified that economic-based approach is more efficient in meeting the challenge compared to traditional non-economic based approach [1,2]. Economic models help to diagnose distributed scheduling problem while ensuring sufficient motivation to the resource providers. Price is a key term of any economic model and can be used to characterize different resources. Price can also be used to maintain equilibrium between supply and demand or sometimes to figure out the true value of resource demands. Different economic models have different pricing strategies and interaction protocols between users and providers. This adds dynamics in the Grid environment.

In spite of the potential that economic models offer, selecting a particular model out of multiple models is challenging; since, 1) the standards of a particular model would be static; however, Grid is dynamic 2) a particular model could only provide limited features to utilize the potential of the Grid, while Grid users could have different aspirations from the Grid and finally, 3) examining the sustainability of a particular model in a large variety of scenarios is harder. We conducted an extensive survey on

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different economic models in Grid computing [3]. We addressed the suitability of different economic models for different scenarios. This inspired us to conduct an extensive experimental analysis of the different economic models. Therefore, in this paper, we investigate, compare and contrast the performance of five most widely proposed economic models in the Grid. We consider a range of different parameters to evaluate the models and identify the regions/scenarios where a particular model outperforms all others. Our findings would help one to decide which model to use when and for what purpose. In this work, we particularly focus on provider strategy; therefore, our solutions are based on giving flexibility only to Grid providers.

Section 2 provides some related work. Section 3 explains the development of the five economic models. Section 4 talks about the experimental setup and simulative study. Section 5 summarizes the paper. Section 6 gives the conclusion.

## 2 Related Work

Realizing the distributed resource management problem in Grid, Buyya et al. propose several economic models [4]. Not all the models proposed are suitable for Grid computing all the time [3]. English Auction (EA), Continuous Double Auction (CDA), Commodity Market Model (CMM), Contract-Net-Protocol (CNP) and Bargaining (BAR) are the five most widely proposed models in the Grid we will discuss in this paper. An extensive explanation on these models has already been given in [4]. We describe the core concepts of the five economic models in Section 3.

Despite the significance of economic-based resource collaboration, there are only a few papers that analyze the performances of multiple economic models in the Grid [5,6,2]. Richard et al. propose that CMM would be suitable for maintaining market equilibrium and minimizing communication cost compared to EA [6]. On the other hand, Tan and Gurd criticize CMM due to its system-oriented approach rather than being incentive-oriented [5]. They argue, in CMM, price formation process considering global information on supply and demand does not account for individual's preference optimization; thus become undesirable for the participants [5]. CDA is proposed to be suitable compared to single-sided auctions such as EA in terms of communication and time efficiency [5].

It has been identified that EA is suitable to maximize revenue, economic efficiency (pareto-optimality in resource allocation) and the QoS [1,2]. CNP has been found to be suitable for the utility-based resource allocation and scalability [7]. It is also suitable to solve the distributed cooperation problem and to optimize meta-scheduling process. On the other hand, in a distributed environment such as Grid, BAR is proposed to be suitable; because it supports utility-based negotiation between a user and a service provider [8].

Due to the extensive and arbitrary nature of the Grid, Resinas et al. identity fundamental components for developing automated negotiation systems (ANS) in an open environment [9]. They describe several properties including prerequisites for supporting various negotiation models. On the other hand, a more focussed research on supporting multiple negotiation models in grid environment is studied by Brandic et al. [10]. They propose a meta-negotiation process to deal with the cross-interests of grid entities. Their generic negotiation architecture would help the grid users to choose their suitable protocols before establishing the Service Level Agreements with the providers. However, neither of the papers extends the protocols to study user or provider benefits. In our research, we investigate the performance of the five most widely proposed models – EA, CDA, CMM, CNP and BAR - and identify their domains of strengths based on different performance metrics including user and provider benefits.

# 3 System Design and Development

To test the performances of the economic models, we use GridSim simulation toolkit. It is a discrete-event Grid simulation toolkit designed for large scale heterogeneous grid entities' simulation [11]. The toolkit also supports the simulation of economic based resource management across distributed domains. By default, GridSim provides EA and CDA. We extend the existing EA and CDA to support deadline parameter. Additionally, we contribute CMM, CNP and BAR to the current GridSim distribution. The following subsections explain this contribution in detail. Before moving on to the models let us briefly describe about the simulation entities, which are common for all the models.

## 3.1 User

Grid users can be characterized using their respective applications/Gridlets which need to be executed on the Grid resources. A Gridlet can be defined as a function of several parameters and is denoted by *gl(id, length, dl, budget)*. Where,

*id* = Gridlet's identity,
*length* = Gridlet's processing length in MI (Million Instruction),
*dl* = Deadline to finish processing the Gridlet,
*budget* = Budget available to process the Gridlet.

A Grid application can again be composed of several tasks. Based on the relationship and dependency among the tasks, Grid applications can be categorized into three types; Bag of Tasks[1], MPI (Message Passing Interface) and Workflow. Currently our work is suitable only for Bag of Tasks applications.

## 3.2 Broker

In a Grid environment, the broker representing a user plays an important role by discovering and communicating to the resource nodes, submitting Gridlets to a suitable node and finally gets the results back from the execute-node. The crucial task for a broker is to process its Gridlet within the budget and deadline as requested by the user.

[1] This kind of applications consist of multiple independent tasks requiring no communication among the tasks [12].

### 3.3 Resource-Node

Each resource-node is configured by some resource properties. If a resource-node is denoted by *n*, then it can be characterized as *n(Id, mList, alloc_policy, cost)*, where,

| | |
|---|---|
| *Id* | = Node identity, |
| *mList* | = Number of machines the node is comprised of. A particular machine further is a function of number of Processing Elements (PE) and Million Instruction per Second (MIPS) rating for each PE, |
| *alloc_policy* | = Job scheduling policy by the node, |
| *cost* | = Cost per second for using the node. |

To obtain the reflection of supply-demand variation, we assume that there is one machine per node and each machine contain one PE with varied MIPS rating or one can assume that all the resource-nodes are part of a big master-node. We employ space-shared allocation policy for the resources in all the models. From henceforth, we use the term "Gridlet" to refer to the *broker*.

### 3.4 English Auction Interaction Protocol

We consider the auction of ascending-bid type (Forward EA). This version of auction type is mostly proposed for the Grid [3]. The most crucial part of the auction is *Auctioneer*. It conducts the auction process among the interested Gridlets.

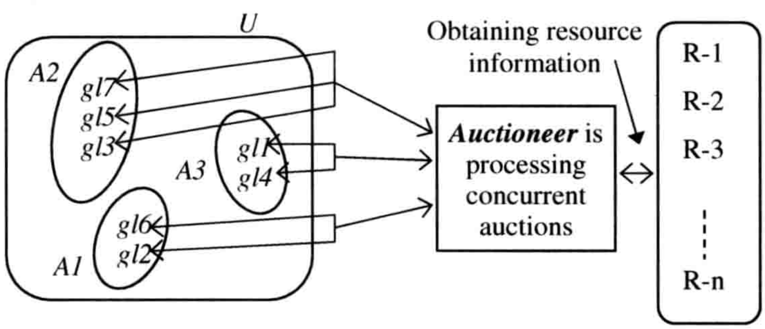


**Fig. 1.** Forming groups of interested bidders in EA

In our simulation scenario, multiple auctions can process concurrently which is consistent with a distributed market scenario. However, in such a scenario, a single Gridlet cannot participate in multiple auctions at the same time. The *Auctioneer* first obtains the information about resources for which the auctions are about to start. Since different Gridlets could choose different resources to compete, *Auctioneer* then requests for interested Gridlets by broadcasting the resource(s) properties to all the Gridlets. This is illustrated in Fig. 1 which describes how different Gridlets choose different resources to compete. It can be seen from Fig. 1 that Gridlet-1 and Gridlet-4 have selected node-3 for competition; since they form the group as *A3*. If the set of available Gridlets in the market is $U$ and the set of interested Gridlets for a particular resource $n$ is $A_n$, then,

$$A_n \subseteq U \quad where, |A_n| \geq 1$$

Let a Gridlet, $gl$ be the element of $A_n$ if the respective resource $n$ can meet the Gridlet's deadline; because if the resource is unable meet the Gridlet's deadline, there is no means to compete for the resource. Therefore, before start processing the auction(s), *Auctioneer* groups the Gridlets (bidders) depending on the Gridlets' deadlines and resources properties. The *cpuTime* of a particular Gridlet, $gl$ on a resource node $n$ is given by,

$$cpuTime = gl\text{-}length \;/\; MIPS\text{-}rating\ of\ n \tag{1}$$

If there are multiple groups competing for multiple nodes, then an auction for each node starts independently with its respective set of Gridlets. Once, the *Auctioneer* gets the $A_n$ ready, it sends the call-for-proposal (*cfp*) to its corresponding Gridlet(s) for a counter-proposal. A *cfp* typically contains total number of rounds $\theta$, current number of round $\theta_c$ and a *current-bid* the *Auctioneer* proposes. The bid typically starts with 0 and keeps increasing over rounds. Over each round, Gridlets decide whether to accept or reject the *current-bid*. We use the same strategy to change the *current-bid* over rounds by the *Auctioneer* as defined in the GridSim.

$$current\text{-}bid = current\text{-}bid + \{(max\text{-}bid - min\text{-}bid) \;/\; (\theta - 1)\}$$

Detailed simulation parameters are appended in Table-1. The auction continues until the total number of rounds finishes or no Gridlet is willing to accept current *cfp*.

We solve the *Winner Determination Problem* using the following two conditions,

- Gridlet that accepts the latest *cfp* and
- the bid in the *cfp* must satisfy the *cpuCost* of the Gridlet

The second condition acts as a reservation price for the resource. As we are comparing the performances of different economic models, we employ this reservation price for every model. The advantage of this price is that no resource will be provisioned below its original execution cost. In case of auction failure, the failed Gridlets are again prompted to compete for other resources for which no auction has yet been initiated. The *cpuCost* of a Gridlet $gl$ on a resource-node, $n$ is given by,

$$cpuCost = gl\text{-}length * (cost\text{-}per\text{-}sec \;/\; MIPS\text{-}rating\ of\ n) \tag{2}$$

### 3.5 Continuous Double Auction

We design the CDA of its most popular form, open cry with order queue [5]. In this form, resource costs (*asks*) are generated continuously until the *Auctioneer* finds a match between a *bid (cfp)* and an *ask*. *Bids* and *asks* can be placed any time during the auction phase. Outstanding bids and asks are maintained in an Order Book while *bids* are sorted in descending order and *asks* are in ascending order. The most important part of the protocol, *Auctioneer*, is described below (Algorithm-1).

Algorithm 1 is the extended version of the existing CDA in GridSim to support deadline parameter. A similar algorithm is designed to handle new *asks*. Unsuccessful *bids* and *asks* are maintained in their respective Order Books. The *bids* are sorted in the Book in terms of their budgets and *asks* are in terms of their costs.

**Algorithm 1. On_Receive_Bid**

```
Input: bid, ask-Order-Book, bid-Order-Book
Output: match/mismatch, Order-Books
if (size of asks-Order-Book > 0)
    {Get the first ask from the  asks-Order-
    Book
    Cast job from the received bid
    Cast node properties from the ask
    Get budget and dl from the job
    Compute cpuCost and cpuTime using (2) &
    (1)
    if (budget • cpuCost & dl • cpuTime &
    node-status = free)
    {Inform the Auctioneer about the match
    finalPrice = (cpuCost + budget) / 2
    Update the  asks-Order-Book by removing
    the ask
    Set the node-status = busy}
    }
    }
else add the bid in the  bid-Order-Book
```

## 3.6 Commodity Market Model

The essence of CMM is to change resource price frequently based on supply and demand function. The price that brings the equilibrium between supply and demand in the market is called *equilibrium/spot price*. We use linear algorithms to determine the *spot price*. According to linear equilibrium theory, the demand and supply functions are given as,

$$Q^D = -aP + b$$

$$Q^S = cP + \alpha$$

Where $Q^D$ refers to the quantity demanded at any specific time and $Q^S$ is for supply; *a*, *b* and *c* are the scalar parts where *a*, *c* are the change in demand and supply respectively, *b* is the *current_demand* which is defined by the number of available Gridlets in the market still looking for resources. The values of *a*, *c* are ranges from 0 to 1. The negative sign in demand function presents the relationship between price (*P*) and demand, which is, an increase in price will induce a decrease in the quantity demanded and vice versa. In supply function, $\alpha$ refers to the shift in supply which can be manipulated as,

$$\alpha = (initial\_supply - current\_supply) / initial\_supply$$

$$\alpha = 1 - (current\_supply / initial\_supply)$$