Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises

Information and Regulation in Decentralized Marketplaces for P2P-Grids *

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Abstract

Large scale systems such as the Grid need scalable and efficient resource allocation mechanisms to fulfil the requirements of its participants and applications while the whole system is regulated to work efficiently. Economics inspired models have shown ability to handle efficiently the allocation of resources and services, scaling up well as they are decentralized. Our model considers the arbitration of decisions at the local scope and short term, the regulation of the system at global scope, and the sharing of information between global and local environments. This paper presents a scalable model and evaluates by simulation a system where global market information circulates in aggregated and scalable form, the rate of demand by participants is globally regulated by a currency mechanism, preference is regulated by a reputation mechanism, and local regulation among competing participants is resolved by auction mechanisms. The paper shows how scalable systems benefit from distributed marketplaces supporting global information flow to regulate and optimize local and global behavior.

1. Introduction

The last years has seen the emergence of the Grid, large scale and dynamic systems formed of thousands or even millions of elements where participants use and provide resources and services, join and leave the system at will. The Grid requires mechanisms to regulate the share of resources between such self-interested parties.

The principal issue for resource allocation is that of arbitrating resource assignment when demand and supply do not match. Straightforward arbitration policies such as those based on priorities may be abused by users if they are free to set their own priorities. Hence, we require mechanisms that provide users incentives to regulate their demand or to self-limit. On the other hand, resource owners need incentives such as economic compensation to share their resources. Pricing of resources establishes common scales of value across different resources. Market institutions such as auctions may be used to price resources and to allocate them to who value them the most.

Markets are an efficient and fair allocation mechanism and accommodate diversity in demand and supply. They are recognized as suitable for heterogeneous environments such as the Grid. Besides, markets are efficient, adapt to fluctuating supply and demand and provide feedback on prices. We propose a collection of efficient, scalable and decentralized mechanisms to regulate and optimize local and global behavior allowing traders to adjust to changing market conditions.

The reminder of this paper is structured as follows. Section 2 presents relevant market based resource allocation frameworks. Section 3 points out some of their limitations and motivates our discussion. An outlook on the component architecture building our framework is presented in Section 4. Finally, Section 5 and 6 show preliminary simulation results and present our conclusions respectively.

2 Related Work

Recent years have seen a flourish in research on market-based Grid resource allocation though, in our analysis, few address large-scale Grid.

Tycoon [9] is designed to trade time-shared networked nodes and implements a proportional sharing auction where each user is attributed a capacity proportional to its bid. Such divisible usage of CPU is not appropriate to a wide range of applications. Besides, a per-node auction as designed in Tycoon does not scale in number of users and machines. Tycoon strictly assumes a closed economy where consumers should be providers and it does not implement a trust and reputation mechanism that aids users in selection

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of auctions. Besides, even though the market is decentralized, Tycoon's banking service is centralized.

GridBus [13] is a resource marketplace that uses non-coordinated brokers to match tasks to resources. The system is organized as a federation of resource nodes managed by a set of co-operating brokers. Brokers of each node either locally accept a submitted job or forward it to a cheapest remote node. The assumption of co-operation can in general not be warranted. A globally deployed reputation service to regulate choice in the market with trust and confidence is not considered yet.

PeerMart [6] implements distributed auctions by associating a broker for each resource/service type. Brokers are implemented as peer-sets on a structured P2P overlay. Synchronization of peers in the set and detection of malicious behavior is necessary to avoid peers' collusion when modifying user's accounts, although it introduces significant message overheads. Segmentation of markets puts the onus on the clients to choose between equivalent resources. Furthermore, PeerMart does not provide support tools to formalize agreements amongst participants.

CATNETS [4] proposes a middleware architecture to provide economic and market based resource management. Scale is addressed by completely decentralized auctions. Their mechanism avoids the knowledge of global information such as an average price for a certain product in the market. Additional services for the regulation of choice such as global reputation and regulation of demand such as currency are missing.

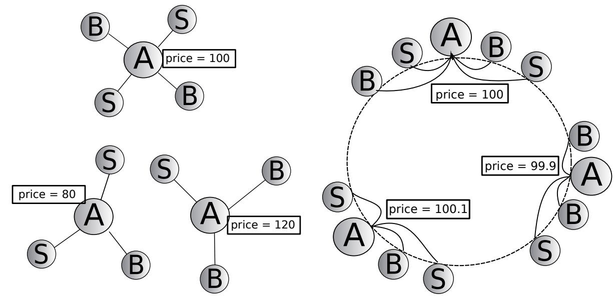
Recent work [5] focus on decentralized peer-assisted content distribution by identifying highly demanded files by means of pricing mechanisms. Besides, their system is designed to fairly deliver content by rewarding most those peers sharing highly demanded content. Therefore, they do not consider price convergence using scalable global information in the presence of different kind of resources to be share –e.g CPU, storage or bandwith– such as in a Grid scenario.

3 Motivation and scenarios

Market theory [12] provides mechanisms to regulate and optimize resource allocation within a local (micro) and global (macro) scope for large and dynamic systems. This section presents a list of requirements to consider for an adequate market infrastructure and scenarios where mechanisms are introduced to address these requirements.

Fair allocation of resources with decentralized auctions. The system must be perceived to be fair, i.e. to allocate resources to those who value them most, but should ensure that there is no lock-out or starvation of some traders.

Centralized auctioneers are a bottleneck in large scale resource markets. Decentralization may be addressed in different ways: PeerMart associates an item to an auctioneer and manages a set of independent markets, but this does not



(a) Independent markets (b) Market with global information

Figure 1. Market Scenario

prevent one auctioneer from becoming a hot-spot. Catnets manages bi-lateral negotiations and provides scalable infrastructure for trading partners to locate each other. However consumers need to simultaneously negotiate with multiple partners in cases where a single provider cannot satisfy the entire request leading to an exposure problem. In our approach we do restrict the ways that the market may be partitioned by supporting on-the-fly creation of auctioneers that could broker in one or more of the following ways:

- By resource type –e.g. CPU or storage market.
- By item –e.g. CPUs of 1Ghz.
- By location –e.g. traders in Barcelona or Sydney.

Auctioneers may also execute different types of auctions –e.g. a combinatorial auction or a double auction. Such a system with multiple independent and simultaneous auctioneers may result in hot-spots and imbalance in number of bidders or ratio of supply and demand creating inefficiency in allocation. Global awareness is required to help the participants to make the right choice of auctioneers thus preventing this imbalance.

Global information of the market. Global market awareness is essential to design negotiation strategies that allow participants to detect and select the best trading opportunities matching its business models. Bergemann's survey [1] demonstrates the importance of economic information disclosure and shows the increased attention paid to economic information acquisition.

Traders require information that enables them to deduce: entry prices, market at which they may efficiently participate and when they participate. Centralized markets are able to furnish the current information necessary for simple or sophisticated bidding strategies – such as ZIP agents [11] or human traders. Therefore, this is an issue for distributed and segmented markets. Distribution and segmentation of markets result in loss of information such as prices, products and effective supply [2]. An efficient information system should allow participants to choose a compromise between exact global information and partial information. Besides, aggregated, anonymized and summarized information contribute to scalability and may in most cases be sufficient.

Global information is necessary to cope with locality and heterogeneity of pricing. Distributed auctions in any of the previously cited ways could result in the system fragmenting into independent and isolated trading clusters. The expected result is divergence in prices and inefficient allocations. Figure 1(a) shows a scenario of fragmentation in a decentralized environment. Sellers and buyers are trading in different markets with no information exchange between the different instances. Moving traders between auctions could help prices to converge as shown in Figure 1(b).

Flexibility in settlement. The resource market architecture should also support the settlement phase –i.e. payment and delivery of resources. Different kind of resources and their usage may need different payment protocols. Thus, the settlement process should be flexible.

The auctioneer matches winning consumer bids and provider offers and establishes the transaction prices. At this stage, contractual negotiations –such as the payment method– must be initiated. Thus, traders should reach an agreement on the charging method as for example:

- **Pay before service:** it is appropriate for grid services where the cost has been established before access and is independent of the real usage. It is also apposite when consumers are not trusted –e.g. a directory service, where the client pays once for using it as many times as necessary.
- **Pay after service:** this is suitable when service cost is unknown beforehand or when consumers are trusted –e.g. the user acquires one CPU for 1€/hour but the real usage may be shorter.
- **Pay during service:** this payment mechanism is appropriate when trust relationships are not well established. Either party may terminate the contract during its lifetime if the counterparty does not respect obligations, therefore being a potential building block for trust relationships.

Incentives and limitations for regulation. Currency acts as an accounting mechanism in a closed market where providers are also consumers and provides incentives in an open market where providers may exchange its gain against real purchasing power in the open world.

Besides, currency is a medium of exchange that allows Grid clients to express the value of their jobs. The amount of currency owned by a user is a ceiling on its purchase power. Markets fail when endowments are infinite. Traders for Grid resources manage their finite endowment or budget over a period of time. It is clear, that greater the budget of a trader is, greater its opportunity to acquire the desired resources.

For example, an application may be adjusted to variable quantities of resources over time but must finish within a specified time frame. During this period, the application manages its assigned budget so as to sustain its resource requirements, bidding for resources which fits better its utility function –i.e. taking into account the remaining budget and its resource requirements.

Market confidence and trust. Any system requires a mechanism through which any user can be accounted to influence future choices. Accounting of pasts actions can be used to evaluate user's reputation and provide valuable information to other users in the Grid.

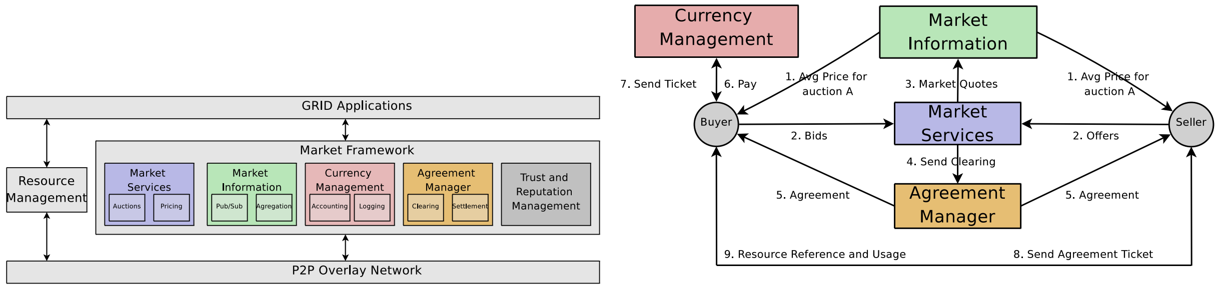
A reputation mechanism constitutes an incentive to Grid users to act correctly. Reputation can be used to limit the effects of dishonest users in the Grid, or to evaluate the quality of service provided by a market. Thus, markets offering poor quality of service may have low reputation discouraging Grid users to place bids on them. Although many approaches exist for maintaining decentralized global reputation [8], there is no market framework providing such information as a core service for markets.

When a contract between a seller and a buyer finalizes, a process to qualify the perceived quality of service must be initiated. Buyers and sellers make use of reputation to qualify the service received by their counterpart. Reputation provides incentives to sellers to offer good quality of service. For buyers, it constitutes an incentive to act honestly so as to be able to be accepted in future negotiations. Reputation provides measures of confidence and trust to the market. Markets can also have its reputation that can be based on the reputation of sellers and buyers participating in them. Thus, markets with higher reputation may be restricted to users with at least certain degree of reputation. Besides, bid submission to markets may also be restricted by the reputation of the bidder.

4 Architecture

We present an architecture, which fulfil the challenges and scenarios presented in Section 3. Figure 2(a) shows the different layers of the Grid market infrastructure. The bottom layer, P2P Overlay, has to deal with basic requirements of distributed systems such as scalability and robustness against failure and churn. Therefore, we choose a structured p2p overlay in order to take profit of its self-* properties. The middle layer is divided into the market component and resources, which use the same communication framework for their interaction. The market component consists of the following five components or services:

- **Market:** The Market Service is a component that mediates the allocation of resources. It can implement different market mechanisms such as double auctions or combinatorial auctions in a extensible way.



(a) Market-Based Grid Architecture

(b) Interaction on a decentralized market-based Grid

Figure 2. Decentralized Market Framework

- **Market Information:** This component provides information to individual market participants such as sellers, buyers or auctioneers. Thus, it uses a publish-subscribe model to inform market participants efficiently and in a decentralized manner with time-sensitive information using a scalable and distributed information aggregation mechanism to handle the load and volume of participants, requests and events in a potentially large scale system [2].

- **Currency Management:** This component provides a mechanism to manage user's accounts representing they current purchase power and a history of transactions in which it has been engaged. Thus, it uses an enhanced DHT able to handle concurrent account modifications when transactions are performed [10].

- **Agreement Manager:** it provides sellers and buyers with flexibility in how to carry out the trading. In Grid applications, the decision of executing the settlement before or after using the product (resources or services), results in significant difference for users and application.

- **Trust and Reputation:** Trust is achieved by a distributed component that accounts reputation of market participants. The component aggregates local trust values without a centralized storage and management facility providing minimal overhead.

The presented scenarios in Section 3 shows how individual challenges are addressed. As a result of complex markets, those challenges might be handled entirely by the presented market infrastructure as depicted in Figure 2(b).

This interaction diagram depicts an use case for buying a resource from a provider. This way, buyer agents may request from the *Market Information* component an average or minimum price, depending on its negotiation strategy.

Derivating the price from this information, it sends a bid for the resource to the *Auction* component. Similarly, the Seller agent publish an offer for its resources to the market.

After the auction successfully matches offer with bids and sends feedback to the market information, an agreement must be reached through the *Agreement Manager* component component.

Depending on the settlement mechanism negotiated, it sends the agreement to both traders informing of the price and the settlement process begins by paying for resources acquired through the *Currency Management* component and, finally, accessing and using the resources in exchange for the payment ticket.

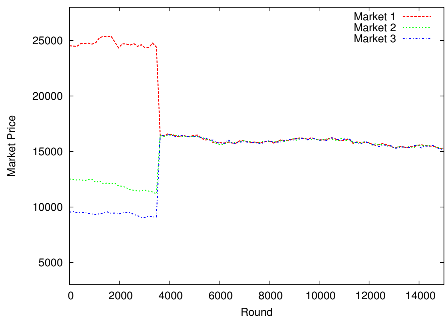
5 Simulation Results

We have performed simulations on different market scenarios to assess the importance of market components previously presented and their capacity to influence and drive traders to a certain equilibrium. For that purpose we have developed a simulator based on GridSim [3] with different modules representing *currency management*, *market information* and an auctioneer performing a *persistent shot double auction* [11], similar to a continuous double auction.

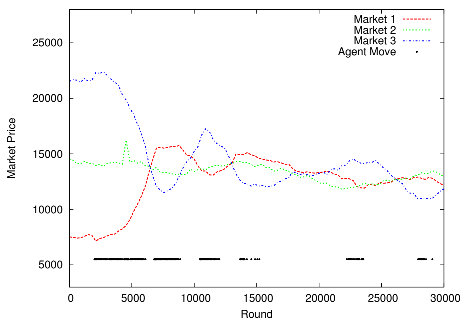
The main objective of the simulations is to point out how mechanisms presented through this paper helps to regulate the system as a whole following simple strategies. Therefore, to simulate an adaptive behavior of individual traders in a certain market, we base our bidding algorithm on extended ZIP agents [11] which are able to reach an equilibrium price depending on market supply and demand with a simple strategy based on the maximum and minimum price of previous bids.

The presence of global market information enables two different agent strategy depending on how they use global information: (a) to change bid pricing in the current auction according to global information and (b) to evaluate whether the current auction is the most adequate or move to another auction.

In the first case, since agents base their pricing strategy on information coming from an aggregate of auctioneers, the effect will be that, despite which auction agents participate in, the outcome will be the same, being equivalent to a single distributed auction. Whereas in the second, auctions are independent and participants may use global informa-

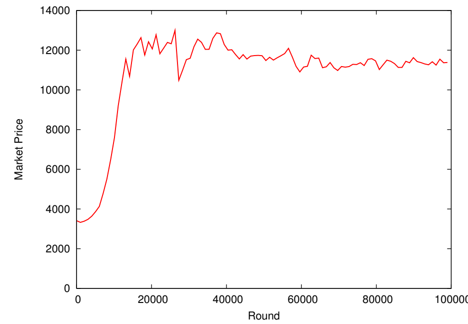


(a) Distributed auctions

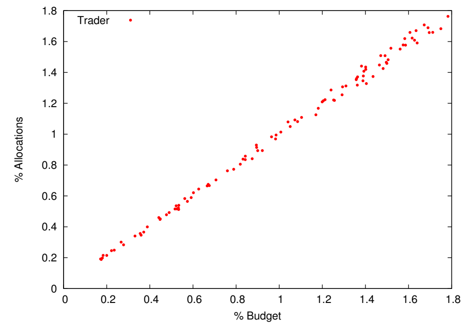


(b) Independent auctions

Figure 3. Effect of global information on different market scenarios



(a) Currency leads to price contention



(b) Proportional ratio between budget and allocations

Figure 4. Effect of currency regulation

tion to decide moving to other auctions more adequate to their needs, leading to a self-distribution of supply and demand between different auctions.

We have done two experiments to evaluate the market behavior depending on the agent strategy, by observing the evolution of market prices. In each experiment, approximately 100 buyers and sellers participate in a setting with 3 auctions with different degrees of imbalance between supply and demand, although the total supply and demand was adjusted to match. After an initial phase without global information, both experiments differ in how agents react to the global market information they receive.

Figure 3(a) and 3(b) illustrate the effect of these two different behaviors. The initial part of both figures shows how three different markets with different supply/demand ratio evolve to a different price equilibrium –i.e. *Market 1* suffers from inflation due to a higher supply; on the other hand, *Market 2 and 3* suffers from deflation as they have more providers than customers. This initial behavior can be observed in a system with multiple independent auctions such as PeerMart.

The other half of both figures shows different behaviors when agents are informed of global market information. On one hand, Figure 3(a) shows how traders use this information to adjust the price of their bids in the current auction. The result is the adaptation of prices among all auctions to a common equilibrium price as if all traders were participating in a single market. The figure shows an stable price given that global supply and demand was designed to be balanced, although traders continue trading in separate unbalanced auctions.

On the other hand, Figure 3(b) shows how traders use this information to move to other auctions more adequate for their needs –e.g. buyers move to cheaper auctions and sellers to auctions with higher price. The result is the adaptation of supply and demand in different auctions leading to an independent price equilibrium for each auction. It shows how the matching price is affected by the movement of agents – points in the figure – amongst markets.

The effect of introducing *currency* and *budget constraints* in the system as a long-mid term regulation mechanism of individual usage has been also evaluated. For this purpose, we set up an scenario where a fixed budget is provided to each trader as in an open economy. After a certain amount of time –called *epoch*–, the budget of buyers is reset with a fixed budget, similarly to [7]. Thus, agents are forced to administer their expenditure strategy to maximize their outcomes.

Therefore, at the end of each *epoch* agents check their remaining budget and decide whether they should increase their spending rate –e.g. in case they did not spent all the budget– or decrease it –e.g. in case they ran out of budget too quickly.

Thus, we measured two dimensions of the effect introduced by currency: price contention and proportional share of allocations. To do so, we simulated a long term scenario (100 epochs of 1000 rounds each) where traders (100 buyers and 100 sellers) try to acquire as many resources as possible taking into account that their budget is refunded at some time interval. Besides, each agent is supplied with a certain uniformly distributed random budget representing their purchase power. Although the presented results are based on a uniformly wealth distribution, other wealth distribution such as Pareto shows similar long term behavior.

For the case of *price contention*, in case agents have an unlimited budget, they might increase their outcomes following a greedy bidding algorithm by increasing the prices arbitrarily but resulting in a high level of inflation. Figure 4(a) shows how agents are forced to adjust their bids to their assigned budget. This way, currency constitutes a price regulation mechanism during peak demand periods.

Regarding *proportional share allocations*, an interesting property introduced alongside with currency is the distinction between traders depending on their budget. The more budget a trader has, the easier should be to achieve its own goals –i.e. maximize the number of allocations in this experiment. Figure 4(b) depicts a linear and proportional relation between the assigned budget and their share of allocations as agents try to adjust their spending rate – therefore, their potential allocations – during different epochs.

6 Conclusions and Future Work

In this paper we discussed the functionalities needed to achieve a decentralized resource allocation mechanism based on markets. Related work fail to address resource allocation in large scale Grids considering both the local and global behavior. Mainly, decentralized markets for large scale Grids require mechanism to account and limit users activity, express users preferences in an scalable manner, provide incentives to consumers and providers to act honestly, provide flexible an configurable settlement policies and provide mechanisms to gather distributed information so as to enable users to be informed about the global state of the economy.

The model and architecture proposed provides not only mechanisms to regulate present concurrent resource allocation needs by decentralized auctions and settlement mechanisms, but also provides mechanisms for the global circulation of information with a decentralized market information service, the regulation of trading with currency to influence the capacity to demand or offer of individual participants and reputation mechanisms to influence future choices. Therefore we provide a scalable and decentralized system that can work and can be regulated on the large-scale as it was a small-scale centralized system. Finally, our preliminary results show how those mechanisms can be used to regulate the overall system and influence selfish individual participants to reach a global fair behavior.

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