Matchmaking through Economic-based Approaches in Ad-hoc Grids

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Abstract—
In this paper we present an overview on different economic-based approaches for resource allocation in Grids. We consider economic models as a platform for matchmaking where consumer and producer of resources meet. The main contribution of the paper is to provide a deeper understanding of the choices one can make as far as economic approaches for resource allocation is concerned.

Keywords: Grid, Economic approaches, Resource allocation, CDA

I. Introduction

Resource management and scheduling in the Grid environment is a complex undertaking as resources are (geographically) distributed, heterogeneous in nature, owned by different individuals or organizations with their own policies, have different access and cost models, and have dynamically varying loads and availability. To manage such complex environment, traditional approaches which attempt to optimize system-wide measure of performance can not be employed. Due to the complexity in constructing successful Grid environments, it is impossible to define an acceptable system-wide performance matrix and common fabric management policy [7].

Conventional resource management schemes are based on relatively static models when a centralized controller manages jobs and resources. Indeed, they focus on efficient allocation schedules which can optimize a given performance metric such as allocation time, resource utilization or system throughput. These management strategies might work well where resources are known in advance. However, this fails to work in heterogeneous and dynamic systems where jobs need to be executed by computing resources whose availability is difficult to predict. Where centralized approaches show some evident limitations, a completely decentralized approach also poses specific problems. Where it seems rational that each node can decide whether it needs additional resources or on the contrary wants to sell them, the main challenge is to make sure they find the resources needed or a user of their resources. One way to provide such a facility is to use economy-based approaches. In this way decentralization is provided by distributing the decision-making process across all users and resource owners. In an economy, decentralization is provided by the fact that economic models consist of agents which selfishly attempt to achieve their goals.

In this paper, first we have a look at the resource scheduler algorithms and policies in Grid systems , then we study different economic-based approaches. Two main class of economic-based mechanisms is discussed and a frame work for matchmaking between consumer and producer agents is presented.

A. Resource Schedulers/Brokers in Grid

Resource management is a complex task involving security, fault tolerance along with scheduling. Schedulers determine the structure of the resource management system and scalability of the system. Resource broker/scheduler is responsible for matchmaking between consumer requests and producer offers. Scheduling algorithms can be classified into:

- **Centralized**: In this model all jobs are submitted to a single scheduler which is responsible for scheduling them on the available resources. Since all the scheduling information is available at one single position the scheduling decision are optimal but this approach is not very scalable in a Grid system. Condor-G[8], Nimrod-G[4] and GrADS[1] are instances of such schedulers.
- **Decentralized**: In this model there is no central scheduler, scheduling is done by the resource requestors and owners independently. This approach is scalable and suits Grid systems. But individual schedulers should cooperate with each other in making scheduling decisions and the schedule generated may not be the optimal schedule. Based on whether or not schedulers cooperate they can be further classified as cooperative or non-cooperative schedulers. For instance NodWis[15] and KARMA[19] are based on decentralized scheduling model.
- **Hierarchical**: In this model the schedulers are organized in a hierarchy. This model is a combination of two centralized and decentralized models. In this model, the scheduler at the top of the hierarchy is called super-scheduler/resource broker that interacts with local schedulers in order to decide schedules. ARMS[5] is an instance of such systems.

Scheduling policies could be system or user centric:

• **System-Centric**: Based on this policy the scheduler does scheduling to maximize the overall throughput of the system. For instance in determining the priority of a job by the scheduler, system policies like ordering jobs according to the basis of submission time is considered.
• **User-Centric**: Based on this policy besides the system parameters the user's needs are applied in scheduling. For instance user constraints such as deadline and budget are considered in determining the priority of a job by the scheduler.

Because of the heterogenous nature of the Grid, managing resources in Grid needs approaches which are both system and user centric. System centric approaches are traditional ones which attempt to optimize system-wide measure of performance such as overall throughput of the system. On the other hand, user centric approaches concentrate on delivering maximum utility to the users of the system based on their QoS requirements, i.e., a guarantee of certain levels of performance based on the attributes that the user finds important such as the deadline by which the jobs have to be completed[3]. Resource management based on economic approaches in addition to providing motivation for resource owners to contribute their own resources to the Grid, they also provide user centric performances. In theses mechanisms, as nodes individually decide according to their own preferences, the utility received by each individual node is being taken into account in addition to the overall utility of the system.

II. ECONOMY-BASED GRID

Economic models have been used widely in resource allocation algorithms [21] [2]. Resource allocation based on microeconomic approaches can be identified in two, price-directed and resource-directed (non-price based) approaches [10][6] (see Figure 1).

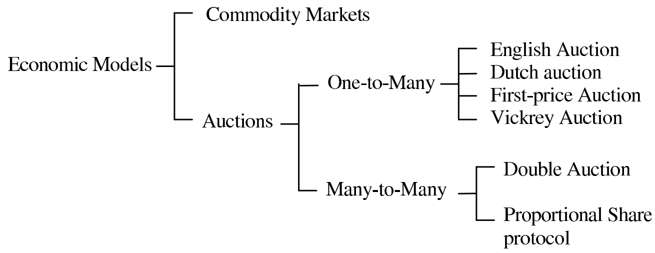

Fig. 1. Economic Models

A. Non-Price Based Mechanisms

Non-pricing approaches are either selfish or cooperative [9]:

A.1 Game Theory-Based Mechanisms

In these selfish mechanisms that rely on game theory [18], each user performs selfish optimization and has its own utility function, independent of the others [22],[23]. The typical example of this approach is coalition formation, where self-interested agents form a coalition to pool their capabilities and resources to solve their own problems more efficiently and less expensively [17],[16],[12].

A.2 Cooperative Mechanisms

Unlike selfish approach, cooperative method has a global utility function which is known to all nodes in the distributed system. For instance, in [11], it is used to allocate resources (such as files or file fragments) in a cooperative and non-competitive manner among agents (computer systems). During each iteration, each agent computes the marginal value of each resource it requires given its current allocation of resources. These marginal values are then sent to other agents requiring use of this resource. The allocation of the resource is then changed such that agents with an above average marginal utility receive more of this resource and agents with a below average marginal utility are allocated less of the resource.

B. Price-Based Mechanisms

In the price directed approach, consumers and suppliers interact via market mechanisms for allocating resources. In a price based system, the resources are priced based on the demand, supply, and the wealth in the economic system. Two main broad of mechanisms for setting prices are: commodities markets and auctions. In both, the main components are consumers and producers and a third party that functions as a mediator between consumers and producers.

The third party in commodity market that is named market, sets a price for a resource (or a bundle of resources) based on demand and supply. The allocations are done based on reaching an equilibrium price where demand equals the supply. The third party in auction models is auctioneer that determine the sale of an individual resource (or resource bundle) based on the bids. Only one bidder is awarded a resource per auction round and the process is repeated for each available resource. The basic philosophy behind auctions is that the highest bidder always gets the resources, and the current price for a resource is determined by the bid prices.

B.1 Commodity Market Model

In this approach, a buyer expresses its demand by requesting for the resources and a seller expresses its supply by the offering its free resources. Market calculate price based on the demand and supply. The buyers and sellers then update their demand and supply based on the new price. They change the requests and offers considering their utility and objective to take more advantages of the market.

In this model, the prices vary with the demand and supply of the resources. When the prices are fixed, the allocation of resources is performed. The price is calculated based on tatonnement process [14]. The tatonnement process varies the price of the individual or bundle of resources until an equilibrium is reached. The equilibrium is achieved when the demand for the resource is equal to the supply of the resource. The price in the $i + 1^{th}$ iteration based on the current price is calculated as: $P_{i+1} = P_i + (E_i/S_i) \times P_i$ in which $E_i = D_i - S_i$. Where E_i is the excess demand,$D_i$is the demand, and S_i is the supply of the i^{th} commodity.

B.2 Auction Model

The most common auction protocols are **one-to-many** and **many-to-many** auctions. In one-to-many auctions one agent initiates an auction and a number of other agents can make a bid . The English auction, Dutch auction, first-price sealed-bid auction, second-price sealed-bid belong to this category.

In many-to-many auctions, several agents initiate an auction and several other agents can bid in the auction. Double auction is the most widely used auction protocol for many-to-many auctions. In these auctions, buyers and sellers are treated symmetrically with buyers submitting requests and sellers submitting offers. There are two types of double auctions, **continuous double auction (CDA)** and **periodic double auction**. Continuous Double Auction matches buyers and sellers immediately on detection of compatible bids. A periodic version of the double auction instead collects bids over a specified interval of time, then clears the market at the expiration of the bidding interval. The Proportional Share Protocol (PSP) is a similar protocol to Continuous Double Auction, as both use a centralized scheduling algorithm. In this approach, the amount of resources allocated to a task depends on its bid price in relation to the sum of bid prices of all tasks executing on that server. Proportional Share Protocol is proposed for the scheduling of tasks in computational clusters [20].

within auction based economic models, pricing is driven by how much value users place on the service and access to Grid services is won by the bidder whose valuation comes closest to that of the resource owner [3]. In these models, there is no global information available about the supply and demand and buyers and sellers usually are not aware of the other's bids or asks and they decide on their local knowledge.

III. Resource Allocation in Ad-hoc Grids

The problem we are looking at is the resource allocation in high throughput computing Grid. In High-Throughput Computing, the Grid is used to schedule large numbers of loosely coupled or independent tasks, with the goal of putting unused processor cycles (often from idle workstations) to work. Condor[13] is an instance of such kind of applications that manages pools of hundreds of workstations around the world and allows the use of idle CPU cycles among them. We are particulary interested in ad-hoc Grids in which the availability of resources and workloads are highly dynamic. Therefore, the consumer and producer of resources have to compete with others to acquire the required resources or tasks.

We aim to provide an economic-based mechanism to allocate computational resources in a heterogeneous and dynamic network. In such a network, whenever any node has some idle resources may offer them to the Grid and on the other hand whenever every node has some tasks waiting for some resources may request them from the Grid. As already discussed computational economies are broadly categorized into two types: Commodity Markets and Auctions. We study these models in different aspects to come up with a suitable model for ad-hoc Grids.

A. *Commodity Markets and Auctions: similarities and differences*

In this section, we compare the two models in more detail:

- In both formulation, consumers and producers appeal to a trusted third party to mediate the necessary transactions.The third party in a commodities market setting, is termed as "market" and in auctions as "auctioneer".
- In commodity markets, the market sets a price for a resource and then queries both producers and consumers for a willingness to sell and buy respectively at that price. Those wishing to participate agree to transact business at the given price point and an exchange of currency for resource take place. The market observes the unsatisfied supply or demand and uses that information (as well as other inputs) to set a new price. Price setting and transactions may occur in distinct stages, or may be concurrent or asynchronous. Alternatively, prices may be set through an auction. In auctions, auctioneer collects resources offers and bids along with the bid and ask prices from consumers and producers. Strategy is to grant the resources to the bidders that bid the highest price.
- In commodity markets, an attempt is made to satisfy all

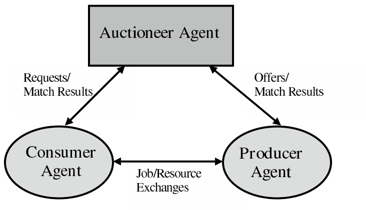

Fig. 2. System components

bidders and sellers at a given price, on the other end, in auctions, one bidder and seller are satisfied at a given price.

• Commodity markets treat equivalent resources as interchangeable. A buyer of resource buys one of those that are available from a pool of equivalent choices without the ability to specify which resource exactly will be purchased. Alternatively, in one-to-many auctions, every consumer bids for a specific resource provided by a producer. In many-to-many auctions resources can be interchangeable.

• In Commodity markets, the complexity in implementation is high, as market has to calculate price based on supply and demand functions which are the functions of the aggregate behavior of all the buyers and sellers. On the other hand auctions are easier to implement.

Considering what discussed above, the auction models can be selected as a proper platform for matchmaking between consumer and producer of resources. Commodity markets rely on polling aggregate supply and demand repeatedly to calculate the equilibrium price and all allocations are performed in this price. As in ad hoc Grids the resources are not dedicated and the supply and demand in the system is very dynamic, the complexity of implementing such centralized market which rely on the aggregate supply and demand becomes high. Among the auction models, continuous version of double auction suits the dynamic nature of ad-hoc Grids. As in this type of auctions, each consumer or producer can spontaneously arise whenever has a need for the resource or a resource to offer. Moreover, the auctioneer continuously collects the requests and offers instead of collecting them in a specified time intervals. Therefore, the deadline constraints for requests and offers can be fulfilled more efficiently.

IV. Economic and Agent-based Framework

In the last few years, there has been an increase in research that combines the disciplines of multi-agent systems and economics. When the agents need to decide on task assignments, then a decision should be made on which agent will carry out a given task. Most of these questions can be resolved by providing the agents with a monetary system, modeling them as buyers and sellers of tasks and resources (consumers and producers). Most economic models introduce money and pricing as the technique for coordinating the selfish behavior of agents. Each consumer is endowed with money that it uses to purchase required resources. Each producer owns a set of resources and charges consumers for the use of its resources. The performance criteria of the system as a whole is determined by some combination of the performance criteria of the individual agents. The effective agents (both consumers and resource producers) in computational Grids are inherently self-interested because of their different ownerships. Self-interested agents make their own decisions according to their budgets, capabilities, goals, and local knowledge without considering the global good of the entire Grid.

A. System Components

The model is composed of three agents (see figure 2): **Consumer (buyer)**, **Producer (seller)** and **Auctioneer**. There is one consumer/ producer agent per node. A consumer/producer agent controls the process of buying/selling resources by estimating the execution time of the job or availability of the resource, calculating the price and generating and submitting a request/offer for corresponding job/resource. The auctioneer agent controls the market using a **Continuous Double Auction Protocol**.

B. Continuous Double Auction

The market works in the following simple manner: the buyers and sellers announce their desire to buy or sell resources to the market. The auctioneer finds the matches between buyers and sellers by matching offers (starting with lowest price and moving up) with requests (starting with highest price and moving down). When a task query arrives at the market place, the protocol searches all available resource offers and returns the best match which satisfies the task's constraints (such as resource quantity, time frame and price). If no match is found, the task query object is stored in a queue. The queries are kept in the queue till the time to live (TTL) for them is expired or a match is found. When a resource becomes available and several tasks are waiting, the one with the highest price bid is processed first.

Pricing policy adopted by auctioneer can be classified into **uniform-price policy** and **discriminatory policy**. In uniform policy, all exchanges are occurred at the same price determined in auction clearing stage; in contrast in discriminatory policy, the prices are set individually for each matched buyer-seller pair. In this work we adopt Continuous Double Auction with discriminatory pricing policy. We choose CDA, as in an ad-hoc Grid availability of resources and tasks may change at any time and using a continues version of double auction, the producers and consumers can submit their offers and requests at any time they have available resources or need for resources. Discriminatory policy is selected for auctioneer in our model. So, auctioneer does not calculate one price for all transactions, instead, transaction is executed in the average of the two buyer-seller prices for each matched pair. In the case of uniform price, many nodes may not be able to afford the price calculated by the auctioneer as their budget is limited.

V. Conclusion

In this paper, we have an overview on different economic approaches which can be used for resource allocation in ad-hoc Grids. Considering the dynamic nature of ad-hoc Grids, Continuous Double Auction mechanism is a proper platform for matchmaking between consumer and producer of resources. As in such mechanism, the buyers and sellers are treated symmetrically with buyers submitting requests and sellers submitting offers at any time they need resources or they have free resources to offer which is the case in ad-hoc Grids. We present an agent and economic based framework for resource allocation in ad-hoc Grid which is based on CDA. In this model, there is no global information available about the supply and demand. Consumer and producer of resources are considered as selfish agents which are not aware of the other's bids or asks and they decide on their local knowledge and preferences.

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