Auction Oriented Resource Allocation in Grid Using Knowledge Based Pricing Policy

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Summary
In this paper, we implemented an auction–based framework for user and resource provider matchmaking in a grid. Auction models are often applied in the existing grid research, as they are easy to implement and are shown to successfully manage resource allocation in the grid market. The focus on the current work is on grid resource allocation based on Continuous Double Auctions (CDA). A continuous double auction allows many users and resource providers to continuously submit bids for the purchase and sale of a service. However, the basic form of the CDA has unnecessarily high price volatility, which causes dissatisfaction among participants. This paper presents a knowledge based pricing policy for CDA in order to reduce the unnecessary price volatility.

Key words:
Simulation, Grid, Continuous Double Auction, Pricing Policy, Bid, Ask, Price Volatility

1. Introduction

In a Grid environment where producers and consumers compete for providing and employing resources, trade handling in a fair and stable way is a challenging task. The fairness must be in terms of price settings with right incentives, offering of grid services should be supported by a suitable resource allocation, accounting, and pricing scheme. As economic theory tells, auctions do have the potential, if applied in a sensible manner, to achieve these fairness criteria. Auction-based models have been used widely in resource allocation algorithms [1] [2]. Auctions for grid computing are normally classified into two categories; one-side auction and two-side auction. In one-side auction one trader initiates an auction and a number of other traders can make a bid. The English Auction, Dutch Auction, First-Price Auction, Vickery Auction belong to this category. The basic concept behind these auctions is that the highest bidder always get the resource and the current price for a resource is determined by the bid prices [3][4][5]. The two-side auction such as CDA creates competition on both sides by allowing users and resource providers to compete with their group to obtain the best resource provider (in case of a user) or the best user (in case of a service provider). As a result, it is expected to yield a better allocation as compared to one-sided auction. Due to the complex and dynamic nature of CDA, it is necessary for participating traders to adjust its bidding behavior dynamically according to the current market state. How to develop an effective bidding strategy adaptive to changing market circumstances is one of the topics in the research of CDA for a long time[6] [7][8][13]. Several researches have been reported on auction mechanisms for resource allocation in Grids [9][10][11]. Pricing schemes based on the auction model having an autonomous pricing mechanism was proposed by [12][14][1], in which prices were decided by grid traders within their trading process. [15] implemented a market-based resource allocation mechanism using Continuous Double Auction model and demonstrated the pricing behavior in balanced and unbalanced network conditions. Our proposed strategy differs from the previous related approaches in the sense that we introduced a knowledge based dynamic pricing policy adopted by auctioneer to determine the transaction price for the current matched shout(bid or ask) between user and resource provider. We further demonstrated how this policy can help in reducing the price volatility, a basic problem associated with traditional CDA.

2. Performance Metrics of Auctions

The most common auction performance measurements include *allocative efficiency* and *coefficient of convergence*. We start by considering the profit of individual traders. If the j^{th} transaction matches a seller with private value Θ_{s_j} and a buyer with private value Θ_{b_j}, setting at price p_j then:

$$\mathrm{P}_{s_j} = p_j - \Theta_{s_j}$$

is the profit that seller makes and: $\mathrm{P}_{b_j} = \Theta_{b_j} - p_j$ is the profit that the buyer makes from trade. Given the private values of all of the traders in an auction, we can calculate not only the profit that each individual makes, but also how the total profit or *surplus* actually made S_a as

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compared to the maximum profit that theoretically could be made S_t. This measure is the *allocative efficiency,* $alloc_e$ usually expressed as a percentage.

$$alloc_e = \frac{S_a}{S_t}$$

The actual surplus is easy to compute from the profit of individual traders:

$$S_a = \sum_{j=1}^{n}\left(\Theta_{b_j} - p_j\right) + \sum_{j=1}^{n}\left(p_j - \Theta_{s_j}\right) \quad \forall\, n \text{ transactions}$$

The theoretical surplus can be computed by establishing the *equilibrium price,* Ξ. The equilibrium price is defined as the price at which supply and demand are equal. Given the equilibrium price, S_t is computed as the sum of profits that would be made by buyers and sellers when all transactions have taken place at Ξ. Thus, overall *allocative efficiency* is given by:

$$alloc_e = \frac{\sum_{j=1}^{n}\left(\Theta_{b_j} - p_j\right) + \sum_{j=1}^{n}\left(p_j - \Theta_{s_j}\right)}{\sum_{j=1}^{n}\left(\Theta_{b_j} - \Xi\right) + \sum_{j=1}^{n}\left(\Xi - \Theta_{s_j}\right)}$$

The coefficient of convergence, α, measures how far an active auction is away from the equilibrium point. It actually measures the deviation of transaction prices from the equilibrium price:

$$\alpha = \frac{1}{\Xi}\sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(p_j - \Xi\right)^2}$$

The coefficient of convergence is also considered as the price volatility in the auction.

3. System Model

The grid computational environment consists of users, resource providers and auctioneers. Users have jobs to be done and are willing to pay for it. Each user U_i has its corresponding resource broker BR_i and submits their jobs to the resource broker. A resource broker performs appropriate resource discovery by participating in suitable auctions, bid handling and job submissions to selected resources as shown in Fig.1. The request message submitted by broker BR_i to auctioneer on the part of user U_i is a tuple $(ID^{(i)}, \tau_{ID})$, where $ID^{(i)}$ represents the ID of one of the job pertaining to U_i as a user can have multiple jobs to be executed and τ_{ID} is the reserve price i.e. the upper bound price the user is willing to pay for the execution of current job. Resource providers have computational resources and are willing to rent them for profit. The offer message submitted by resource provider RP_i is a triplet (ID, τ_{ID}, d), where ID represents the resource ID, d contains information about the resource characteristics such as architecture, CPU speed and τ_{ID} is the reserve price i.e. the lower bound price the resource provider is willing to charge for the execution of a job.

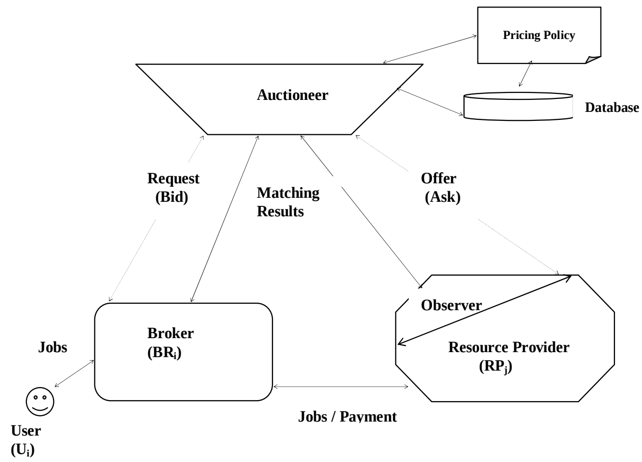


Fig. 1 Auction-based grid components

Each resource provider has an observer which is responsible for handling all messages related to auction such as preparing the ask prices, sending them to auctioneer and receiving the results of the auction from auctioneer. Auctioneer is deploying a CDA with knowledge based pricing policy. In this model, bids (users) and asks (resource providers) may be submitted at any time. Whenever there are open bids and asks that can be matched or are compatible in terms of price, a trade is executed immediately.

4. Knowledge Based Pricing Policy

In traditional CDA, multiple users and resource providers are allowed to submit bids and asks in an auction for homogeneous resources and the auction clears whenever a bid and ask match resulting in continuous nature of CDA. A pricing policy defines how transaction prices are determined from the shouts made by the traders. In traditional CDA, a typical pricing policy is adopted where the auction clears at a weighted average of the bid and asks as given in the following equation with $k = 0.5$:

$$p = k.p_b + (1-k).p_a$$

where p_b is the matched bid and p_a is the matched ask. Determining the transaction prices merely on the basis of current matched bid-ask pair usually result in large price volatility in the system. In order to have a check at price volatility, we maintain a knowledge base containing all previous matching pairs of bids and asks used to set the transaction prices. According to this policy, if Φ is the latest transaction and knowledge base is currently having information regarding M number of transactions then the transaction price, p_Φ, of Φ with p_{b_Φ} and p_{a_Φ} as the accepted bid and ask, can be obtained as:

$$p_\Phi = \frac{1}{2.(M+1)} \sum_{i=1}^{M+1} (p_{a_i} + p_{b_i}) \text{ where } M+1^{th} \text{ entry}$$

entry corresponds to Φ transaction

and $p_{a_\Phi} < p_\Phi < p_{b_\Phi}$

The resulting modified continuous double auction algorithm executed by auctioneer is as follow:

(CDA)$_{\mathbf{KPP}}$ - **C**ontinuous **D**ouble **A**uction with **K**nowledge based **P**ricing **P**olicy

1. Auctioneer collects all bids $(p_{b_1}, p_{b_2}, \cdots, p_{b_r})$ all asks $(p_{a_1}, p_{a_2}, \cdots, p_{a_s})$ and then it sorts all asks in increasing order:

$p_{a^{\alpha(1)}} \le p_{a^{\alpha(2)}} \le \ldots \le p_{a^{\alpha(s)}}$ and all bids in decreasing order:

$p_{b^{\beta(1)}} \le p_{b^{\beta(2)}} \le \ldots \le p_{b^{\beta(r)}}$ where α and β are the permutations defining the order statistics.

2. When a RP_i submit a new ask p_{a_i} to the auctioneer then it does the following activity:

a) if $p_{a_i} \le p_{b^{\beta(1)}}$ then auctioneer informs $BR_{\beta(1)}$ and RP_i that they can deal at price $\tilde{p}$ obtained as (taking $p_{b_i} = p_{b^{\beta(1)}}$):

$$\tilde{p} = \frac{1}{2.(M+1)} \sum_{i=1}^{M+1} (p_{a_i} + p_{b_i}) \quad \text{where } M+1^{th} \text{ entry}$$

corresponds to i^{th} transaction and $p_{a_i} \le \tilde{p} \le p_{b_i}$

b) if $p_{a_i} > p_{b^{\beta(1)}}$ then auctioneer inserts p_{a_i} to an appropriate position in the sorted list of current asks.

3. When a RB_i submit a new bid p_{b_i} to the auctioneer then it does the following activity:

a) if $p_{b_i} \ge p_{a^{\alpha(1)}}$ then auctioneer informs the RB_i and $RP_{\alpha(1)}$ that they can deal at a price $\tilde{p}$ obtained as (taking $p_{a_i} = p_{a^{\alpha(1)}}$):

$$\tilde{p} = \frac{1}{2.(M+1)} \sum_{i=1}^{M+1} (p_{a_i} + p_{b_i}) \quad \text{where } M+1^{th} \text{ entry}$$

corresponds to i^{th} transaction and $p_{a_i} \le \tilde{p} \le p_{b_i}$

b) if $p_{b_i} < p_{a^{\alpha(1)}}$ then auctioneer inserts p_{b_i} to an appropriate position in the sorted list of current bids.

4. Go to step2.

5. Simulation Results and Discussions

Based on the model and pricing algorithm presented above a functional and performance investigation has been undertaken. We developed a simulator in java to evaluate the performance of (CDA)$_{\text{KPP}}$ running on a Pentium 4 1.73 GHz laptop. The simulator facilitates the evaluation of (CDA)$_{\text{KPP}}$ in terms of transaction price. We simulated a grid environment in which any number of users and resource providers can participate during each round of continuous double auction. Key rules for the parameter selection are as follows: for users, the bid of each resource is within the range $\lfloor p_{b_l}, p_{b_u} \rfloor$, for resource providers, the ask of each resource is within the range $\lfloor p_{a_l}, p_{a_u} \rfloor$ with the constraint $p_{a_l} \le p_{b_l}, p_{a_u} \le p_{b_u}$ to lower the possibility that too many bids of resource provider are higher than bids of users. The screenshots of our developed (CDA)$_{\text{KPP}}$ based simulator are shown in Fig. 2 and Fig. 3.

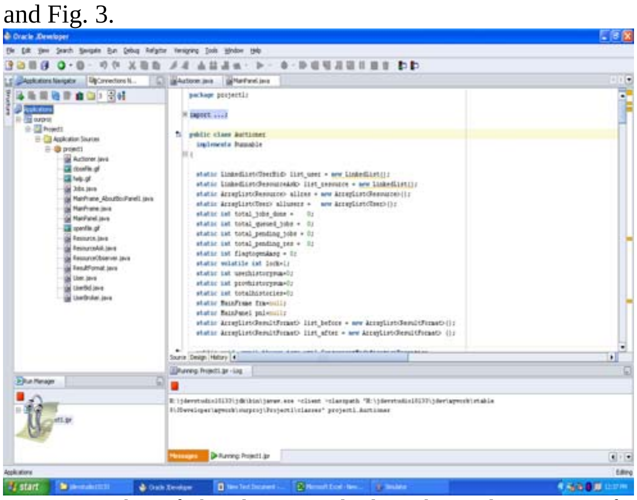


Fig.2 Screenshot of the classes involved in the implementation of proposed model and pricing policy.

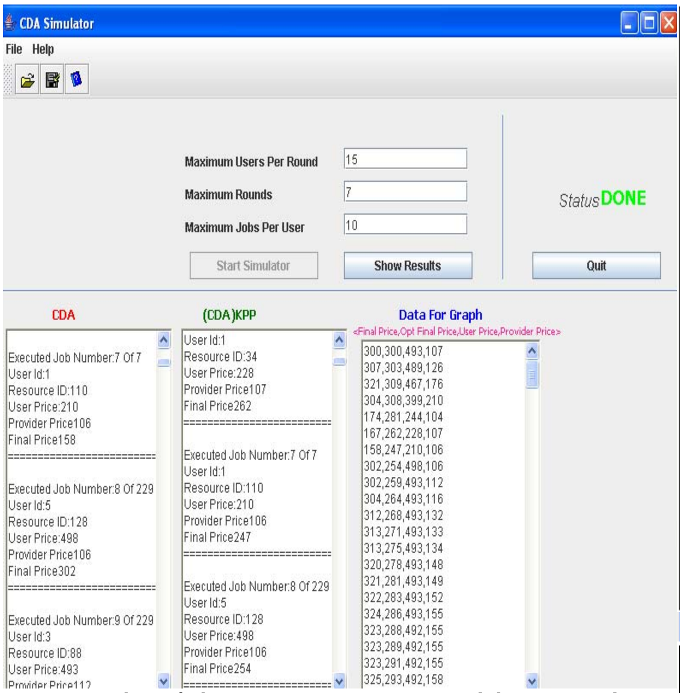
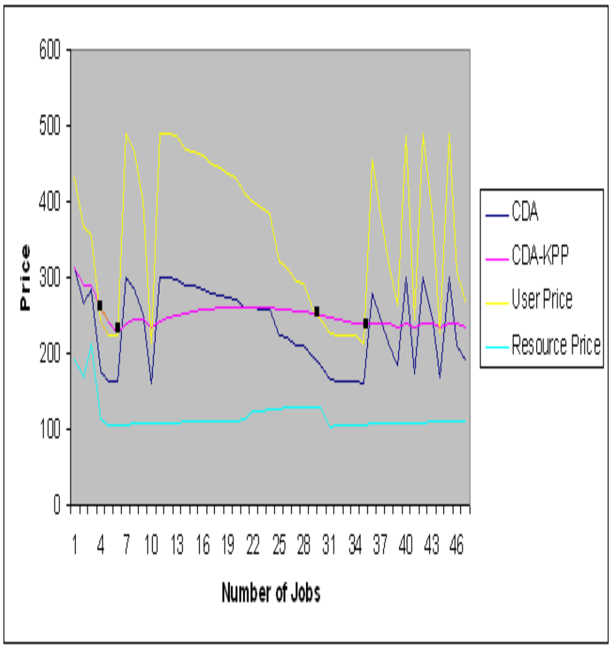
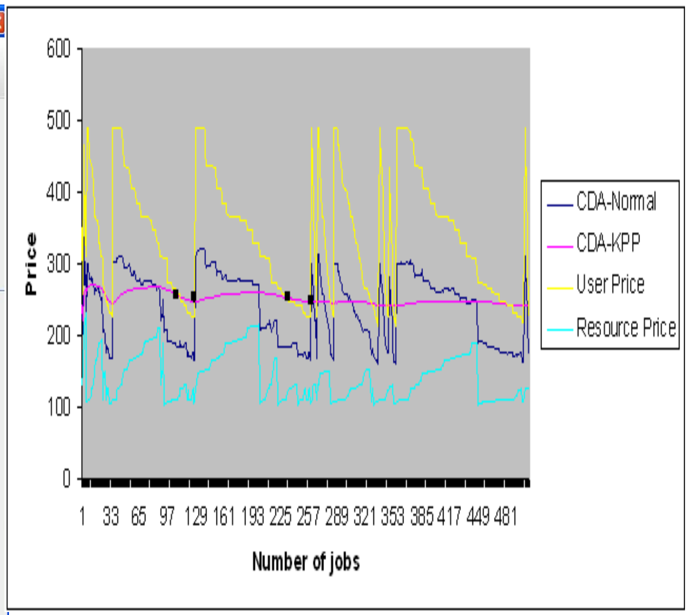


Fig.3 Screenshot of the transaction prices generated by CDA and $(CDA)_{KPP}$

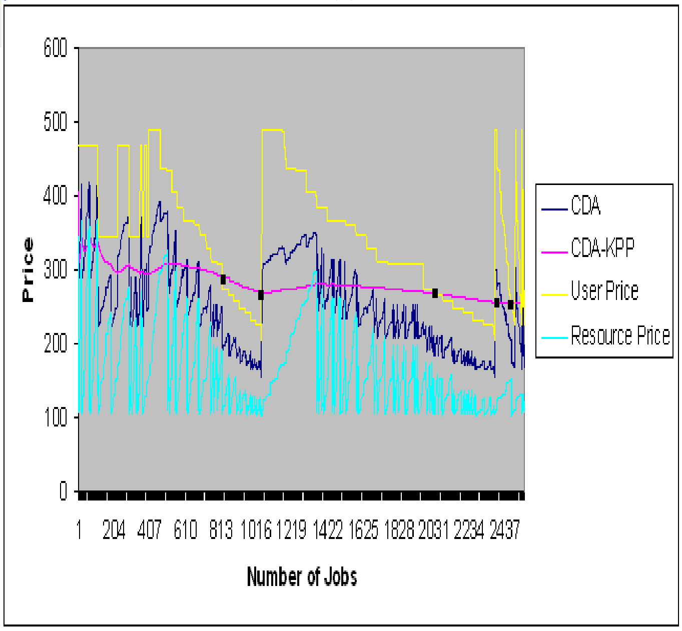
In order to demonstrate the performance of the proposed pricing algorithm, a resource allocation on a larger scale has been simulated. The results of the algorithm are illustrated in Fig.4. It presents the comparison between the transaction prices through CDA and $(CDA)_{KPP}$ along with user prices and resource prices.



(a)



(b)



(c)

Fig. 4 Comparison of the transaction prices using CDA and $(CDA)_{KPP}$ with number of jobs (J), number of users (U) and number of resources (R) as (a) J=48, U=10, R=19 (b) J=507, U=92, R=171 (c) J= 2545, U=170, R=310.

Fig.4 clearly shows that price volatility is significantly reduced in $(CDA)_{KPP}$, besides this, the presence of some dots in these graphs corresponds to regions where user price falls below transaction price. It represents user's losses and it is due to the fact that a user is trying to execute his job within its deadline even by suffering marginal losses.

6. Conclusion

In this paper, an auction allocation model based on a modified Continuous Double Auction protocol is presented. We developed a simulator in java to simulate the protocol and evaluated its performance in terms of transaction price. The results showed that modified protocol $(CDA)_{KPP}$ is significantly better than the traditional CDA in terms of reduction in price volatility.

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