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## ANALYSIS OF AUCTION APPROACH IN CONTROL OF JOB ALLOCATION FOR COMPUTING NODES

**Summary.** In this paper an analysis of auction mechanisms in computer cluster system will be presented. Taxonomy of bidding approaches will be described and some bidding level will be distinguished aimed to control of computing nodes. Vickrey mechanism will be in detail considered and some performance indexes will be evaluated and discussed.

**Keywords:** auction algorithm, management of resources in computer cluster, Vickrey mechanism

## ANALIZA MECHANIZMÓW AUKCYJNYCH DO STEROWANIA ALOKACJĄ ZADANIA DLA WĘZŁÓW OBLICZENIOWYCH

**Streszczenie.** Celem niniejszego rozdziału jest przedstawienie zagadnień i analiza algorytmów aukcyjnych do sterowania klastrem komputerowym. Omówiono taksonomię aukcji oraz etapy licytacji w zastosowaniu do sterowania węzłami obliczeniowymi. Przedstawiono przykład z zastosowaniem algorytmu Vickreya oraz wskaźniki oceny algorytmów.

**Słowa kluczowe:** algorytmy aukcyjne, sterowanie klastrem komputerowym, algorytm Vickreya

### 1. Introduction

Very intensive demand for an exchange various types of data in computer networks being observed in last years and increasing the speed and the total volume of data transfer caused that a smart network management strategy should be implemented to assure fluent operation of the system. Especially demanding operation is managing of the effective delivering of

video and voice streams or files for distributed computing systems. The software need to flexible control of the system and grant in the proper time all necessary resources for successful operation the given task. One of possibly strategy in automating controlling user requests is the idea based on the auction approach.

The fundamental auction algorithm can be applied in many specific versions. The taxonomy of the auction mechanism will be discussed in the second section of the paper. The next section is a review of the reported application known from the literature. In the fourth part the problem of scheduling jobs in a computing system with auction approach and load-balancing will be formulated and some solutions would be proposed. In the last section some concluding remarks have been given.

## 2. Classification of auctions

Wolfstetter defines an auction as a mechanism of allocation a set of goods into a set of bidders on the basis of their bids [11]. The rules are known before the bidding process starts. Another definition describes an auction as bidding process in which the winner (who receives the item) will be arisen and the price which must be paid for the item will be calculated. So in a bidding process we can define a set of notions e.g. item, bid, bidders, auctioneers. An item is an object, article which will be sold. A bid is an offer containing price proposed by buyers. Bidders (buyers) are users which want to buy some item. Sellers (auctioneers) are responsible for managing the auction process.

The dependencies between buyers and sellers are shown in Fig. 1 [1]. It should be noticed that bidding process consists of many buyers and only one seller. The role of the seller is assigned to the scheduler (dispatcher) of the cluster.

		Buyer	
		One	Many
Seller	One	<b>Negotiation</b>	<b>Auction</b>
	Many	<b>Reverse auction</b>	<b>Market</b>

Fig. 1. Relations between buyers and sellers

Rys. 1. Relacje pomiędzy kupującymi a sprzedającymi

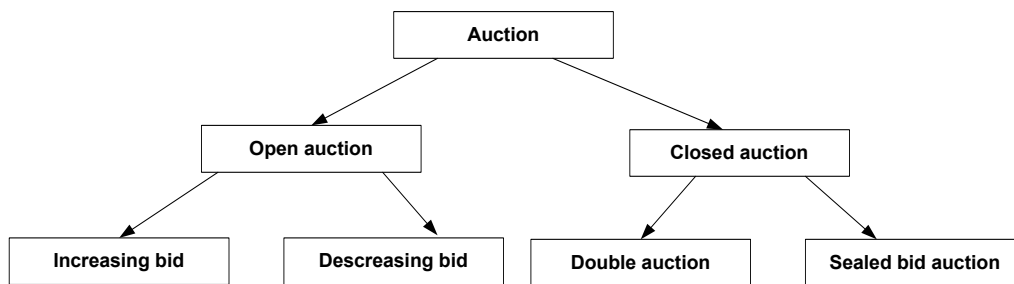


Fig. 2. Taxonomy of auctions  
Rys. 2. Taksonomia aukcji

In the publications there are many classifications of auction algorithms. In Fig. 2 the taxonomy of auction algorithms is shown [4]. On the first level the difference between open and closed auctions would be distinguished.

The inherent feature of an open auction is that the bidding process is fully known for all users, while in a closed one the values of bids are implicit.

Open auctions can be divided into increasing and decreasing auctions, so the value (price) of an item increases or decreases in every interval (auction runs). Closed auctions can be treated as a double and sealed bid auctions. In double closed auctions the bidding process runs twice, whilst at the closed sealed bid auction the price is determined by the  $n$ -highest value, so it can be first or second price auction, so the winner (who offers the highest bid) will pay the highest or the second highest price. The second sealed bid auction is also known as a Vickrey auction. The behaviour and the bid values of every player will be true, so everyone will propose the price, he is willing to pay for the item. On the other hand, when the player wins, he will not pay the price he proposed himself, but the second one in the rank.

Another classification divide auctions as a single or a multi-bid auction (Fig. 3), so in the first group only one bid can be sent to one item from each buyer. Contrary, in the second group many bids are allowed.

In such a type of auctions as shown in Fig. 4 the auctioneer can prepare offers to selected or to all users [15].

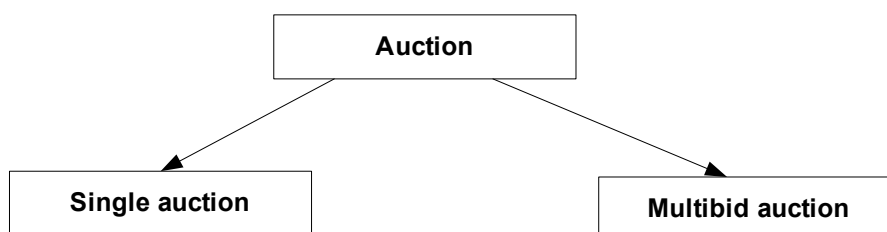


Fig. 3. Taxonomy of auctions based on number of bids from each buyer  
Rys. 3. Taksonomia aukcji bazująca na liczbie ofert licytującego

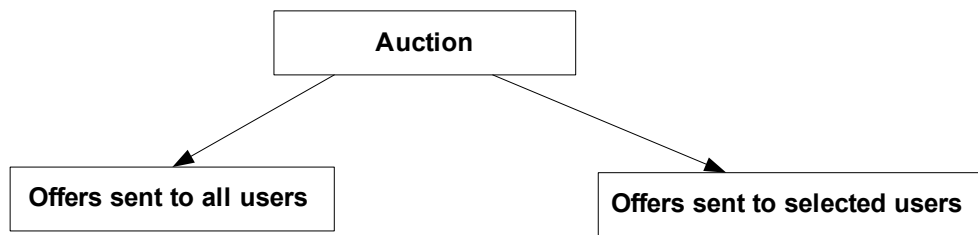


Fig. 4. Taxonomy of auctions based on kinds of offers  
 Rys. 4. Taksonomia aukcji bazująca na rodzajach ofert

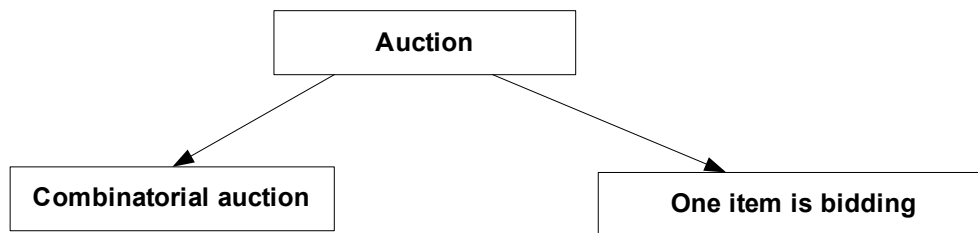


Fig. 5. Taxonomy of auctions based on number of bidding item  
 Rys. 5. Taksonomia aukcji bazująca na liczbie przedmiotów licytowanych

The next classification categorizes auctions into combinatorial or one item bidding auction. In combinatorial auctions, which are growing in recent years many items are bided simultaneously. In this policy there are bidding sets of items, e.g. there are given goods A and B, and the Client\_1 specifies his valuations  $\{A\}$  5\$,  $\{B\}$  3\$,  $\{AB\}$  15\$, and Client\_2  $\{A\}$  8\$,  $\{B\}$  2\$,  $\{AB\}$  9\$ respectively. It can be observed, that the Client\_1 needs both goods whilst the Client\_2 prefers the single property  $\{A\}$ . During analyzing the actual state of situation a WNT (Winner Determination Problem) can be formulated. It must be specified and declared which granting strategy will be preferred. The first proposal is the following: as a Client\_1 gets all items, the second one gets nothing, otherwise the second possible proposal is: granting to a Client\_2 an item  $\{A\}$ , and to a Client\_1 an item  $\{B\}$ . In the second case the profit (gain) is not factually the biggest, but all Clients get some items [7, 11].

In the one item auction schema, only one item is biding separately, so every element of the set will be auctioned independently one by one.

### 3. Applying of bidding mechanism

Auction mechanism is used in many applications such as reservation based networks in bandwidth allocation, in systems power on demand, video or demand or in system electricity on demand [10, 13]. In the paper [3] three original bidding strategies have been described. The first one – “the offer method” is like an advertisement from a server and the client can agree with the offer or reject it. In the second one – “the request for bids methods”

the client can negotiate for both the amount of power and the price he would like to obtain. In the third policy – “the announce reward tables method” server prepares some advertisements for every client. The negotiation process can be explicitly observed in this case, but the values of electricity amount would be limited. In the article [13] a case study of the bidding process of Vickrey auction type is presented in application of allocating the bandwidth needed to the data transfer.

#### 4. Design of auction mechanism in management of computing nodes

A management of the admitted jobs to the queue can be executed in a deterministic or a random manner. Applying of auction mechanism to declare the winner of the bidding process grants him resources necessary to perform the job.

As the cluster resources aren't sufficient to serve all users (clients) requests immediately, so an arbitrating strategy should be established, which will grant goods only to these users (jobs) who could bring the highest profits to the system as a sum of charges for all services.

In this section it will be shown that the bidding procedure can take into account many stages of the cluster management process. The aim of the proposed in Fig. 6 system is to schedule and execute computing jobs from different users in the decreasing bidding order (starting from the maximal to the minimal offer). The length of the queue of the global scheduler is limited, so only jobs with the highest value of bid will be processed.

Some ideas of the scheduling mechanisms will be shown later. At the beginning we define some metrics to compare efficiency of algorithms.

The performance index can be evaluated as:

$$\varphi_1 = \frac{r_1}{r}$$

$$\varphi_2 = c_1$$

$$\varphi_3 = \frac{r_1}{r_2}$$

$$\varphi_4 = \frac{c_1}{c_2}$$

where  $r_1$  is number of all serviced jobs,  $r$  is number of all admitted jobs,  $c_1$  is sum of charges paid by users for completed jobs,  $r_2$  is number of rejected jobs,  $c_2$  is sum of charges of all rejected jobs.

A business performance index  $\varphi_2$  effects in maximizing the income of a server, but the clients interests won't be taken into consideration.

Our thesis can be formulated as follows: that we can't serve all users in the same grade, because the resources are limited, so we will choose jobs maximizing the performance index  $\varphi_2$ .

In the proposed system, shown in Fig.6, the rectangles from  $B_1$  to  $B_N$  represent bids, being created by users. The next rectangle Q shows the global queue, from which jobs will be directed to processing in computing cluster nodes, represented as  $N_1$  to  $N_M$  [14].

We can distinguish three bidding stages while managing the operation of the computation system. The first one takes place between users and the global scheduler. Clients submitting their jobs to the queue, will send their offers to the server (global scheduler). The role of the auctioneer - the scheduler is to choose such jobs, which will maximize the value of a defined metric (business performance index).

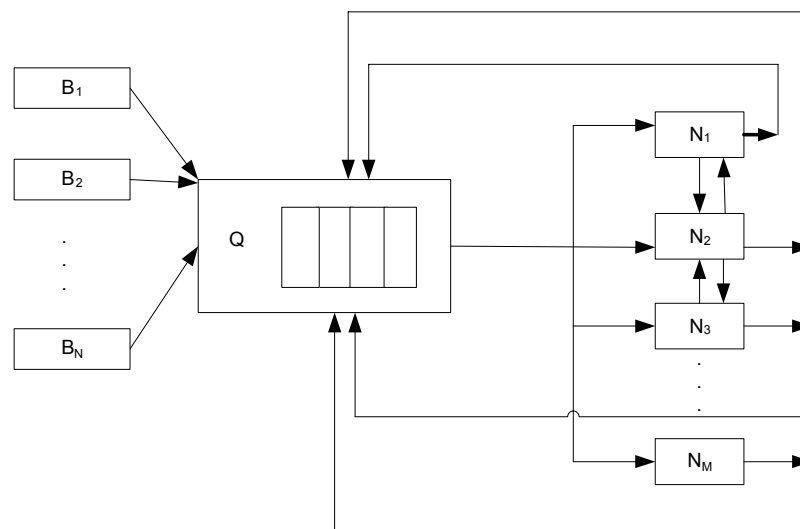


Fig. 6. A management system based on an auction approach used in a computer cluster  
Rys. 6. System zarządzania klastrem komputerowym bazujący na algorytmach aukcyjnych

In the second phase shown in Fig. 6, it can be observed, that the bidding procedure takes place also between global scheduler and computing nodes [6, 14, 15].

In the central mechanism as presented in the paper [2] the main scheduler measures the load of all nodes periodically (in every time interval). Information about the mean load will be sent to all nodes. This strategy provides that the manager will get the actual information about the load of nodes in a real time. Then he will send some offers to selected nodes, and after the bidding procedure will designate the winner, who offers the shortest execution time. The job will be granted to the winner.

The third stage was designed to assure the load balancing of the system. The bidding strategy deals with overloaded nodes and their neighbours. In [12] the idea of describing states of nodes was proposed. The following values were assigned: High, Normal and Low state. The switching of the state has been described in details in the contribution. The

arbitration process effects asking only few nodes, so the decision will be taken very quickly in this case. In Fig. 6 the auction process is represented with the node  $N_2$ , which negotiates with the neighbours.

**Problem formulation:** For the given set of bids, proposed by users, containing a computational task, its price and a given performance index, such a strategy should be found which maximizes the performance and supports load-balancing in the system. During the first phase jobs are submitted, during the second the computation time is optimized and the last stage maintains load balancing in the system. The management algorithm of bidding process of such system could be implemented in the global scheduler and in computing nodes.

### **Proposed algorithms**

The integrated management strategy of the cluster can be based on combining three auction mechanisms. In the first stage application of the Vickrey algorithm is considered [7, 13], so that the winner pays always a lower price than he had declared. As an example three bidders, which sent offers containing similar tasks can be considered. So the classification of similar tasks will be taken in the initial phase, the tasks will be assigned to one class containing similar resources [5,9]. The offers can look like: the first user declares {task1 (class1), price 80 \$}, the second one offers {task2 (class1), price 100 \$}, and the last one {task3(class1), price 60 \$} respectively. Let's assume that two tasks can be chosen from all offers. According to a sealed bid algorithm the offers with maximal prize will be chosen, so offer from the second user and from a first user. The user number two will pay the second highest price comparing to his offer, so he will pay 80\$, and the first user will pay 60\$.

In the second stage of managing computing system is proposed to implement the double auction algorithm to grant the task to the working computing node. Finally on the last stage we propose load-balancing algorithm, sending offers only to selected nodes (neighbours) [14].

An additional algorithm updating the mean execution time for every job class will be implemented in the management module of the scheduler. From every class of jobs it should be chosen defined number of tasks proportional to amount of all submitted tasks.

In the system will be implemented method of assigning tasks to tasks classes based on Cherkasova approach [5, 8, 9, 10].

## **5. Conclusions**

In this paper an auction approach was proposed as the management strategy in the computation cluster providing the load-balancing of the system. The taxonomy of bidding algorithms has been proposed and described. A management control system for computing

nodes has been structured and three-stage combined auction algorithms have been assigned. The practical experiment will run in the real computer cluster environment and the efficiency will be measured in comparison to FIFO manner of granting computing tasks.

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Recenzent: Prof. dr hab. inż. Tadeusz Czachórski

Wpłynęło do Redakcji 25 września 2008 r.

## Omówienie

W niniejszym rozdziale przedstawiono taksonomię algorytmów aukcyjnych oraz zaproponowano mechanizmy aukcyjne do sterowania węzłami obliczeniowymi klastra. Podczas kilku ostatnich lat zaobserwowano wzrost implementacji aplikacji z wykorzystaniem algorytmów opartych na licytacji.

Celem zaproponowanego podejścia jest maksymalizacja biznesowego wskaźnika oceny algorytmu, najczęściej jest to przychód serwera wynikający z przeprowadzonej aukcji. Zadanie polega na znalezieniu czasowo optymalnego uszeregowania ofert, takiego że zasoby klastra będą całkowicie wykorzystane i suma wartości uszeregowanych ofert będzie maksymalna.

Funkcją przedstawionego systemu będzie wykonywanie zadań zgłoszonych i opłaconych przez użytkowników. Użytkownicy będą formułować swoje oferty zgodnie z własnymi preferencjami i cenami licytacji.

Mechanizmy aukcyjne mogą być rozważane na kilku szczeblach zarządzania węzłami obliczeniowymi, np. jako selekcja ofert użytkowników (do globalnej kolejki zadań), jako szeregowanie zadań do węzłów obliczeniowych z globalnej kolejki zadań oraz jako szeregowanie zadań pomiędzy węzłami obliczeniowymi w celu zapewnienia równomiernego obciążenia oraz poprawienia wydajności klastra. W artykule zostanie zaproponowanych i przeanalizowanych kilka algorytmów aukcyjnych, w tym m. in. mechanizm Vickreya.

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