AUCTION BASED SYSTEM FOR ELECTRONIC COMMERCE TRANSACTION

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Abstract: Auctions provide efficient price discovery mechanism for sellers. Auctions are being used for sale of variety of objects. In last few years auction based protocols are widely used in electronic commerce. Auction based systems have been developed for electronic procurement. In this paper we propose system for electronic commerce transactions, which can support electronic procurement as well as help enterprises to sale items. We also consider assignment constraints those may be required in different commercial transactions. In this paper we consider forward and reverse auctions. We formulate the problem as mixed integer programming problem. Then we propose an algorithm to obtain optimum solution and compute pay-off.

1 INTRODUCTION

An auction is basically a bidding mechanism which is described by set of rules. These rules specify how the winner is determined, from the set of competing bids and how much winner has to pay. Auctions have been in use for many years. They are used for sale of variety of objects. These objects range from bonds of public utilities to perishable items like flowers. Governments of different countries use auction mechanism to sale long-term securities and treasury bonds, to raise funds to meet the borrowing needs of government. Similar mechanisms are used by public sector utilities to sale their bonds and raise money. The process of procurement using competitive bidding is another form of auction. In this case the bidders compete for right to sell their products or services. The private and state owned enterprises use different types of bidding mechanisms for procurement of variety of products like computer stationery and this practice is fairly wide spread.

It is also being used to dispose of waste and scrap materials. The rights to use material resources from public property such as mining rights, off-shore oil leases, have been sold by means of auctions in different countries. Communication companies use to similar mechanisms for bandwidth allocation. In real life large number of transactions are carried out using different types of auction mechanisms. Auctions are helpful to seller, as they help them to avoid the risk of determining the price of an object. Auctions provide mechanism, where the price is determined by others rather than seller himself. However seller can decide whether to accept the bids received. Auctions are used mainly for following three reasons

- Auction helps in obtaining/revealing information about buyer's valuations
- Actions are also helpful dishonest dealing between buyers and sellers
- They provide Speed of sale

Traditionally auctions like ascending price or English, descending price or Dutch, or Sealed bid auctions were earlier used in different economic transactions. Emergence of Internet based electronic markets in last years has contributed significantly to growth of different types of auction transactions. This has resulted in significant increase in number of transactions that are being carried out using different types of auction mechanisms on Internet. Present day electronic auctions support novel applications like electronic procurement, bidding on air ticket etc. Different companies use electronic bidding to get market determined prices of their goods. Internet based auction companies such as ebay, ubid carry

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out large number of auctions. Internet based auction companies have implemented many different types of auction mechanisms, apart from traditional auctions like English, Dutch, Sealed Bid. Auction based protocols have been widely used in electronic commerce. Auction mechanisms are widely used in electronic commerce for carrying out negotiations.

One of the most important use of this mechanism is to facilitate the transfer of assets from public to private hands. This has been a common phenomenon in different countries in last two decades as a result of economic liberalization. Governments in countries like Britain and Scandinavia have uses auctions to privatize transportation systems. In former Soviet Union and Easter Europe countries auctions have been used to sale public owned industrial enterprises. Auctions are being used for many years to acquire rights of use of natural resources. Such types of auctions, where government grants access rights to use natural resources or transfers the ownership of its enterprises can be considered as examples of forward and reverse auctions. When government is transferring public owned enterprise, it may be interested in seeing that ownership is distributed appropriately and no one person or enterprise gets ownership beyond certain percentage.

While granting access to natural resource it may be interested to see that no one person or private enterprise acquires complete control. This can give rise to different types of constraints, while determining the winner. In this paper we consider a scenario of forward and reverse auctions under constraints. The main contribution of this paper is the development of algorithm which can minimize procurement cost for enterprises as well as maximize the cost selling. Then design of system for electronic procurement and selling has been presented. Our algorithm also takes into account different types of constraints. We also compute Vickrey-Clake-Grooves (Vickrey, 1961), (Clarke, 1971) (Gooves, 1973) (VCG) payments for buyers and sellers. This ensures that our mechanism is strategy proof and efficient. The rest of the paper is organized as follows, in section 2, we present an example of the problem with different types of constraints and related work. In section 3, we discuss the problem formulation, design aspect of our system and our algorithm. In section 4 we discuss experimental results. In section 5, system implementation is discussed. We conclude in section 6.

2 RELATED WORK AND MOTIVATING EXAMPLE

In this paper we consider the problem of single item multi unit auction problem under different types of constraints. We basically consider two scenarios. In first case there is a single seller having quantity q of an item to sell and there are n buyers. This type of auction is usually called as forward auction. In the second case, we consider a scenario, where there is one buyer and who requires quantity q of certain item and there are n sellers who can supply these items. This type of scenario is called as reverse auction. These types of auction problems have been studied recently (Kothari, 2003). An approximately-strategy proof and tractable multi unit auction mechanism for single good multi unit allocation problem has been presented in (Kothari, 2003). The problem has been modeled as generalization of classical 0/1 knapsack problem and a fully polynomial time approximation scheme for reverse and forward auction variations has been presented. In this formulation capacity constraints, where buyer or seller can express upper bounds on their respective requirements are considered.

However in certain cases in addition to capacity constraints, we can have constraints on number of items that can be sold to one buyer or which can be purchased from a single buyer. We consider an example of Initial Public Offering (IPO) of a government owned enterprise to illustrate this. In IPO government invites competitive bids from different individuals and private enterprises, for privatization. Suppose that government wishes to decrease its ownership in an enterprise from 100% to say 49%. This is done by means of IPO of its shares, wherein government invites competitive bids from individuals and others. Even though individuals or private enterprises may indicate their capacity or willingness to buy certain number of shares, it may not be feasible as per policies of government. The enterprises may be divided in number of categories and the there can be different restrictions This scenario has been shown in Table 1. A government wishes to sale say, one million shares by means of IPO. Suppose that the bids submitted by different companies are as given in Table 1.

Table 1 : Sale of 1 Million shares by IPO

Enter-prise	Price	Min. Demand	Max. Demand	Govt. restriction as % of Tot. No. of Shares (1 Mn)
1	100	2 Lakhs	5 Lakhs	15%
2	105	5 Lakhs	8 Lakhs	30%
3	110	5 Lakhs	1 Million	30%
4	102	1 Lakhs	1 Million	20%
5	100	10 Thous-and	1 Lakh	5%

The third and fourth columns show capacity constraints of different enterprises. The restrictions as per rules governing IPO, are shown in fifth column. These restrictions impose certain constraints. However these constraints are not much different from usual capacity constraints. This may result in change upper bounds and lower bounds in some cases. It can be seen that upper bound on shares that can be sold to an enterprise, is much smaller in respect of enterprises 1, 2 and 5 and is much higher in case of enterprises 3 and 4. So upper bound on capacity constraints of these enterprises will differ. However there can be constraints like total number of shares that can be sold to a particular group. We illustrate these constraints in next table in reverse auctions. In reverse auction also there can be similar constraints e.g. An enterprise has requirement of 10000 meters of clothes. As per government policies, it is required to acquire certain percentage from certain types of sellers (e.g. a small scale enterprises run by group of women etc.). The different quotes received by it are given in Table 2.

As per government policy, the enterprise must acquire half of its requirement for enterprises (1) and (4), which are small scale enterprises, run by group of persons from weaker sections of society. It can acquire remaining requirement from other two enterprises. These constraints are basically on group of sellers. Even though each seller has capacity constraints, the group constraints will apply on a group of sellers (1,4) and (2,3). These constraints differ slightly from usual capacity constraints. We formulate this problem as mixed integer programming problem, which can handle assignment constraints indicated above. Then we present an algorithm, which obtains optimum solution and then computes pay-off based on VCG mechanism. A detailed survey of auction mechanisms can be found in (Wolfstter, 1996). A multi attribute auction system, for electronic procurement has been studied in (Bichler, 1999).

Table 2 : Quotations Received

Enterprise	Price (per Ton)	Maximum Supply
1	105	3000
2	101	10000
3	102	6000
4	103	4000

In multi attribute auctions winner determination is based on more than one attributes unlike in traditional English or Dutch auctions, where price is the only attribute. An application of auction theory in electronic procurement has also been studied in (Eso, 2001), it also gives near optimal solution to bid evaluation problem of the buyer. A procurement process which minimizes the cost using auctions has been proposed in (Kalgnanam, 2001). Another type of auction known as Combinatorial Auctions where seller wishes to sell a combination of goods and buyers bid on one or more goods, has been studied recently (Rothkopf, 1998), (Sandholm, 1999). Double Auctions is another widely used auction mechanism and has been used in different stock exchange markets like (National Stock Exchange of India) and many other stock exchanges worldwide. It is also widely being used in commodity exchanges such as (Multi Commodity Stock Exchange of India) and other similar exchanges. Stocks are homogenous goods, and buyers do not have preferences over a designated stock. Apart from this we are not aware of any work done in developing algorithms to generate optimum solution in case of constraints or exploring other approaches to solve the problem especially in case of forward and reverse auctions.

3 SYSTEM DESCRIPTION AND PROBLEM FORMULATION

We basically consider two scenarios- A forward auction, where there is a single seller having quantity q of an item to sell and there are n buyers, and a reverse auction, where there is one buyer who requires quantity q of certain item and there are n sellers who can supply these items. We first introduce the relevant concepts. One of the important features of our system is the algorithm which obtains the optimum solution i.e. minimum procurement cost or the highest cost of sale under different types of assignment constraints. This algorithm always generates the optimum solution with polynomial time complexity. Another feature of our implementation is an algorithm, which generates the pay off for each participant. We compute VCG pay–off which ensures the properties like efficiency. It also ensures that truthful bidding is the dominant strategy.

A *bid* in the forward auction (an ask in reverse auction) describes the details of the items, its quantity and price that the buyer is willing to pay. Without loss of generality we assume that there are n buyers (sellers). Additionally buyer (seller) can describe capacity constraints. A buyer (seller) can also use the marginal decreasing piecewise bidding language used in (Kothari, 2003). This allows buyer to specify the quantity range and price that buyer is willing to pay as ([10,5),5) instead of single quantity price pair. It is also an ordered list of attribute names and values. Let there be a set of n bids, B_1, B_2,…, B_n. Each B_i (Ai) is of the following type:

$B_i = ((at_1, v_1), (at_2, v_2),…, (at_k, v_k))$,

where at_j denotes the j^{th} attribute and v_j is the value of the attribute.

The *attributes* describe different characteristics of the items. Each attribute assumes the values from the set of specified *domains*. For instance, the price attribute will have values from set of positive real numbers. The price and quantity are two attributes of asks and bids. If buyer (seller) uses marginal decreasing piecewise bidding language, then at_i can be a semi closed interval, which is open at one end. Each buyer (seller) can specify m such intervals and price pair. In this case we select only one point (on an interval) for each buyer.

Our system is implemented as a web based system which can be configured to be implemented by third party auctioneers as well as enterprises. It has got a parameterized policy module using which levels of security, scheduling, type of auctions etc. can be defined. Three different implementation levels of security are provided in the system. In the first level authentication by means of User-Id and Password is provided. Once the user is successfully authenticated, it uses Secure Socket Layer (SSL) protocol for sending any message.

In the second level combination of User-Id, Password and Public Key Cryptography is provided. In this level it uses Public Key Infrastructure (PKI) for implementing security. Each participant (i.e. buyers, sellers, auctioneers) can optionally have a key pair. The public key must be deposited with the specified trusted third party (TTP). In this level use of public key cryptography is optional. In the third level the use of public key cryptography is mandatory. In this case all the participants must have key pair. In this implementation a bid or ask is acceptable only if it is digitally signed by the sender (i.e. buyer, seller or auctioneer). These levels help to provide different levels of security in the system. The level of security can be selected depending upon the value of items. The auctioneer can enforce use of public key cryptography in case of high value items.

Another feature of our system is that its design based on of Event-Condition-Action (ECA) rules. Specific ECA rules can then be bound to different events for versatile exception handling. Number of different types of exceptions and events have been defined in the system.

Events of different types can occur in this system occur because of actions of different parties. The action by buyer of submission of a bid will cause occurrence of event like “Bid Arrived”. This event will trigger activity like “Bid Validations”. This activity will validate the bid. In case the bid is invalid i.e. some of the attributes of bid violate some constraints “Invalid Bid” exception will be raised, sending appropriate notification to sender. In case bid is valid an event “Bid Accepted” will occur. There can be two types of events database events and negotiation events. Events in the system like “Bid Arrived” will be caused by actions of buyers. When the event like “Acceptance Closure” occur, it will automatically trigger of the algorithm to generate optimum solution.

This system can be configured as sealed bid or open depending upon the type of auction. In case of sealed bid option bids (asks) will be submitted in encrypted format and will be decrypted only after the auction has closed. In this case it will not be possible for the buyers (sellers) to see the bids (asks) submitted by others. The system can also be configured to accept more than one bid or ask from a buyer or seller. However sender must specify which bid or ask is final. If the information is not specified then the last submitted bid (ask) is treated as final.

The complete cycle of stages in our system is as follows:

(1) User Registration: The system requires that each participant must register with system, before it can be used. The user details are captured in this phase.
(2) Auction Notification: Once the users are registered with the system they can notify the auction. The details of auctions like item description, type, security level required etc. are submitted by the users to the system. This indicates the start of auction. An auction can be initiated by a buyer or a seller. Optionally it is also possible to submit the reservation price.
(3) Bid/Ask Submission: Once the auction is notified the bids and asks can be submitted by the registered users. At this time price and quantity details are required to be submitted. In

some cases asks and bids are required to be digitally signed by the sender. Multiple asks and bids can be submitted by any buyer or seller, however only one of these bids or asks will be considered. It can be the last submitted bid/ask or any one of the submitted as indicated by the buyer.

(4) Closure: The bids and asks can be accepted for only fixed period of time. After this period asks or bids cannot be accepted. At the end of closing period the auction is cleared.

(5) Clearing and Pay-off: Once the acceptance of bids (asks) is closed, the optimization problem is constructed from the received bids and asks. Then the optimum solution is obtained. After finding out optimal solution, system generates the pay-off of each buyer and seller.

(6) Notification: After generation of optimum solution, VCG pay-off for each buyer and seller is generated. In this phase each buyer and seller is notified about the result of auction and his pay-off.

At present the system is not linked with banking system to execute payments. In the next phase it will be linked with banking system, so that payments can also be effected automatically. In the following paras we describe and state our algorithm for finding optimum solution.

Our algorithm is based on branch and bound method. At each stage it finds out maximum possible improvement. At any given price, maximum improvement is possible only by selecting maximum quantity that can be available at that price. Our algorithm is based on this and works as follows:

(1) We start with the highest (lowest) available price.
(2) Determine the maximum quantity that is available at that price after taking into account all the constraints. If there are two bids (asks) with same price then we combine them.
(3) Save the value of buyer's (seller's) contribution in separate table.
(4) Repeat above two steps till requirement is completely fulfilled.
(5) Then determine VCG Payoff for each buyer (seller).

Let A be the list of asks and B be the list of bids. The algorithms are as follows:

Algorithm (1) forwauct /* Main Algorithm */

1. *Sort all bids on descending order of price within same price sort on descending order of quantity*
2. *While (there is an unmarked bid or unfulfilled demand) repeat steps 3thru 7*
3. *Find out maximum quantity available for price p_i after capacity constraints on buyers and other constraints*
4. *Calculate and save the buyer's contribution*
5. *Calculate the value of objective function*
6. *Mark the bid*
7. *Add quantity to demand_fulfilled*

Algorithm (2) revauct /* Main Algorithm */

1. *Sort all asks ascending order of price within same price sort on descending order of quantity*
2. *While (there is an unmarked ask or unfulfilled supply) repeat steps 3thru 7*
3. *Find out maximum quantity available for price p_i after capacity constraints on sellers and other constraints*
4. *Calculate and save the seller's contribution*
5. *Calculate the value of objective function*
6. *Mark the ask*
7. *Add quantity to supply_fulfilled*

Example: The working of the algorithm is illustrated in the following simple example. There are four asks and five bids. The capacity and other constraints are shown in maximum demand and supply column.

Bid	Price	Qty Avl.	Max. Possible	Tot. Price	Ask Price	Ask Qty	Qty. Req	Cost
1	45	5	3	135	10	12	5	50
2	40	8	5	200	15	12	4	60
3	35	6	6	210	20	8	4	80
4	30	6	4	180	25	8	4	100
5	25	8	8	200				
		33		925				

Solution Example

The output of our algorithm shown in column 4 (forward auction) and last column for reverse auction.

4 EXPERIMENTAL RESULTS

The algorithm has been implemented in C++. The data sets of asks and bids of different sizes were generated randomly. Each data set consisted of number of asks with ask price, quantity, ask size, bid size, bid price and bid quantity. Size of data sets varied from 5 to 1500. The results were compared with unconditional optimum solution and some solutions obtained with the help of MATLAB package. It can also be seen that time complexity of our algorithm is always polynomial. The Figure 1 indicates the comparative performance of proposed solution against algorithm proposed in (Kothari, 2003). The maximum (minimum) quantity at any price can be obtained by scanning at most n asks and bids each time. Apart from this sorting is the hardest part. Since sorting time complexity is of the order of O(nlogn), the time complexity of this algorithm is $O(n^2)$ + O(nlogn) in worst case, which compares favorably with the time complexity order O(n3) presented in(Kothari,2003). Additionally VCG pay-off gets computed in linear time complexity.

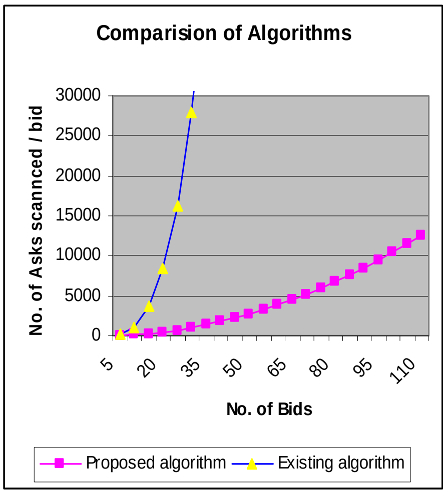

Figure 1: Comparative Performance

5 SYSTEM IMPLEMENTATION

The auction system for purchase and sale transactions which minimizes the procurement cost and maximizes cost of selling based above algorithm has been implemented. The system can handle forward as well as reverse auctions and is configurable. An enterprise can configure the system for forward or reverse auctions and once it is configured buyers can submit bids and sellers can submit asks. Then our algorithm computes optimum solution based on submitted asks and bids. The optimum solution will be either minimum procurement cost or maximum cost of sale. Then it also computes VCG pay-off of each buyer and seller. As VCG implementation has different properties like efficiency, strategy-proof ness, our implementation has also these properties. It ensures that no buyer or seller can gain by untruthful bidding. The UML State Chart Diagram of Figure 2 captures different states of our auction based system. The UML activity diagram is shown in Figure 3. The different modules in the system are

User Registration Module: This module helps buyers and sellers to register with the system. The details of the users are captured here. The users can also submit their respective public keys to the system using this module. The users can also update their respective details. A web interface has been created for submitting the user details.

Notification Module: This module helps users to notify about the auction. An auction can be initiated by a buyer or a seller. A web-based interface has been defined using which users can specify the different parameters. The users can specify the details like whether auction is open or sealed bid, the period for which the auction will remain open, type of auction, constraints and reservation price etc. Once the auction details are submitted this module notifies different buyers and sellers about it. This module also informs users about various activities and status of auctions. Once auctions are notified buyers and sellers can submit respective bids and

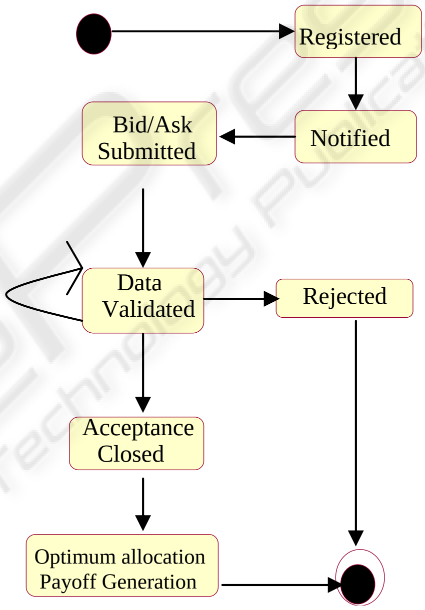

Figure 2: State Chart diagram

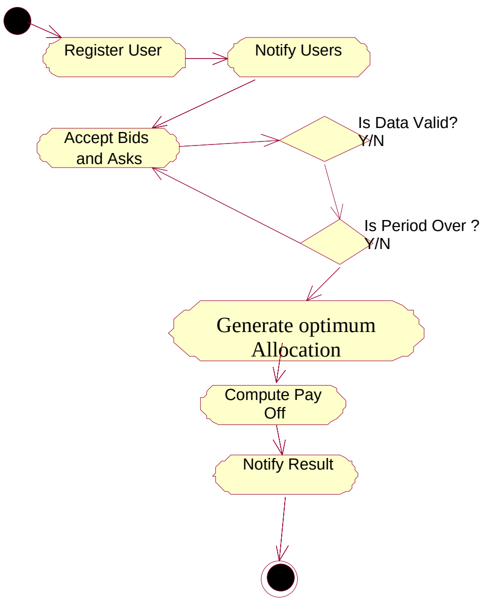

Figure 3: Activity diagram

asks. It also notifies the result of auction and payoff of each buyer and seller.

Bid/Ask Submission: This interface helps buyers and sellers to submit their respective bids and asks. The buyers and sellers can specify capacity constraints using this module. It allows multiple submission till closing time. It helps users to specify their firm bid or ask. It allows the users to digitally sign their respective bid or ask. It can also ensure that each message is encrypted if required.

Validation Module: This module validates the data submitted by users. Each bid or ask is validated. Only bids and asks are considered for further processing. If bid or ask is invalid then corresponding message is returned. It validates the user details and the auction details. If the submitted details are invalid then the data is rejected.

Scheduler Module: This module schedules various activities in the system. Once the auction is submitted it schedules activities like auction notification, closure of bid and ask acceptance, clearing of market etc.

Configuration Module: It helps enterprises to configure the auction system. Different parameters like security level, period, type etc, can be configured based on user requirements. It also helps in User Administration.

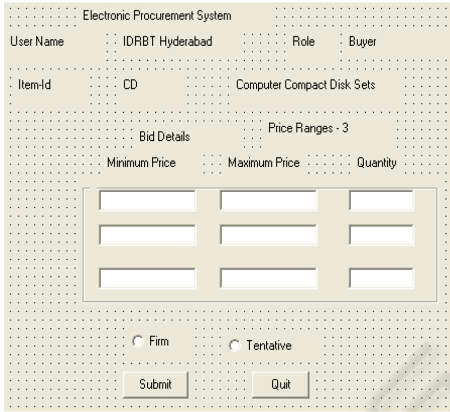

Figure 5: Auction Screen

Optimization Module: This module first formulates the optimization problem depending upon the options, attributes and constraints specified. It then implements the algorithm described in section 3 of the paper. It finds out optimum procurement cost or cost of sale. This is one of the main important feature of our system.

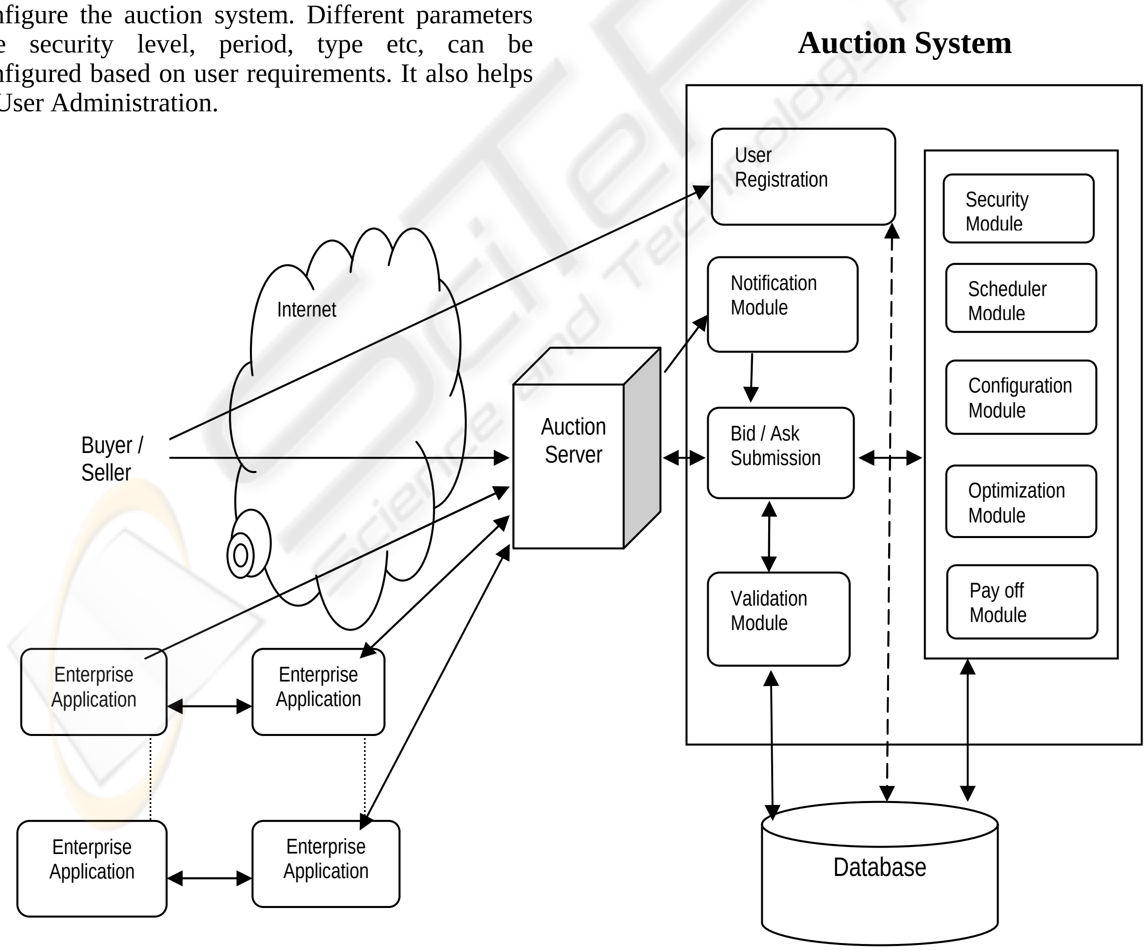

Figure 6: Auction System Architecture

Payoff Module: It computes the payoff of each buyer and seller. It computes VCG Pay-off by fast computation. This module can also backtrack and generate the solution, even if one of the participant backs off.

Security Module: This module provides the security components in the system. It provides services for storage of public keys. It has modules for encryption, decryption and digital signing.

The screen shot our system is shown in figure 5 and architecture in figure 6.

6 CONCLUSION AND FUTURE WORK

In this paper we have presented the design of an auction-based system, which can handle assignment constraints. The two types of auctions considered here are forward auction and reverse auctions.This system can handle different types of assignment constraints in addition to capacity constraints. Its two main components are the optimization algorithm, which generates optimum solution to problem of minimizing procurement cost or cost of sale, considering different types of assignment constraints and pay-off algorithm. This can help enterprises to procure and sell items. It is also helpful in carrying out IPOs for sale of share of any enterprise. They can specify the assignment constraints of different types, so the problem is handled more general settings. The algorithm can also handle unconstrained cases. Our system also ensures that the truthful bidding is the dominant strategy. The future work includes extending this work to solve the problem where quantity is not constrained to be integer. Another extension will be interfacing the system with the existing systems of different enterprises and adding payment component. One of the extension will be to provide secure payment capabilities by incorporating one or more banks in the system.

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