Abstract

An auction is an economic mechanism that is widely used to sell different commodities such as food grains, flowers, real estates, cars and air tickets etc. It is specified by set of winner determination and payment obligation rules. Auctions are commonly used when sellers do not want to decide the price and allow the market to determine the price. Auctions are used in different types of transactions to sell variety of goods. Governments of many countries use different types of auctions for selling Treasury Bills, Bonds etc. Private companies use auction mechanism to sell different types of products like flowers, food grains, diamonds etc. In every day life, auction accounts for enormous volume of trade transactions. Different auction mechanisms differ, basically with respect to winner determination and payment rules. There are different types of auctions like English, Dutch, Sealed bid, which are used in various economic transactions in different types of markets. Auctions have been widely studied in economic literature. In any auction based mechanism, two main problems are

(i) determining the winning bids/asks
(ii) determining how much each participant has to pay/receive.

Auction theory also specifies the set of desirable properties of any auction mechanism. Auction based protocols are widely used in electronic commerce. In many electronic commerce applications different types of bidding mechanisms are commonly used for implementing electronic negotiation. In last few years there has been growing interest in Internet based market places. Ebay, uBid etc. are some of the successful Internet sites, which use auction mechanisms in their operations. Electronic markets leverage on information technology to perform different market functions efficiently and reduce cost of transactions. Electronic auctions in these markets are used in many cases for providing e-negotiation functionalities. Hence large number of auctions are carried out over the Internet. Apart from traditional auctions, many different types of auction systems based on multi attribute auctions, combinatorial auctions etc. are implemented in electronic environment. Double auction is an important auction mechanism, which is widely used in electronic markets. Most of electronic markets like multicommodity exchanges or financial markets for stock are built up around the mechanism of double auctions that involves multiple buyers, sellers, the continuous double auction and a clearinghouse. Another important application of electronic auctions in last few years is privatization of government owned enterprises. However most of these models cannot be directly applied in electronic auctions. This is due to the following reasons.

(1) In an electronic exchange, the object being sold may not be exactly identical (e.g. cotton with different grades).
(2) In an electronic procurement system, the object to be procured is required in different specification or sizes (e.g. paper of different widths).
(3) In case of privatization of government owned enterprises, there may be certain policies of government, which may constrain the ownership beyond certain percentage for group of buyers.

All these requirements give rise to auctions with constraints which have not been studied widely. These requirements means that demand and supply cannot be aggregated across all the bids and asks. Earlier there were few studies of auction
models where buyers have budget constraints [BCIMS2005]. Apart from this auctions with constraints have not been studied widely.

In our work, buyers do not have budget constraints, but constraints arise due to the very nature of electronic auctions. Auctions with different types of constraints are studied in this work. We have addressed two basic problems in the context of electronic auctions with different types of constraints. The problems which have been addressed in the context of electronic auctions are (i) finding optimum assignment of asks and bids in case of different types of constraints and (ii) determining how much each participant has to pay/receive. In this work we have developed set of algorithms to obtain optimum assignment of bids/asks. Payment mechanisms with desirable properties have been developed, so that auction mechanism satisfies desirable properties. The thesis is organized into seven chapters as follows.

(1) In first chapter, the problem of electronic auction is introduced.
(2) In second chapter, earlier work is reviewed in the context of electronic auction.
(3) Third chapter deals with the algorithms for determining optimum assignments and payment mechanism in case of Double Auctions with different types of constraints.
(4) In fourth chapter, a mechanism which is budget balanced strategy proof and individually rational is presented.
(5) In fifth chapter, algorithms for determining optimum assignments and payment mechanism in case of Single Object Multi Unit Auctions with different types of constraints are presented. A financial application of auctions with constraints is presented in chapter 6.
(6) In seventh chapter the future research directions are presented.

We study Double sided auctions under different types of constraints, which provide an efficient mechanism to implement bidding-based many to many negotiations. In these auctions, sellers and buyers submit asks and bids respectively, which are matched and cleared periodically. Efficient algorithms exist to match these asks and bids in case there is no constraint. However in many practical situations there can be different types of constraints in matching the bids and asks. These constraints can be of the form where an ask can be matched with only certain types of bids and vice-versa. In some cases the supply from different asks cannot be combined to fulfill a demand. Such constraints are known as indivisible demand bid constraints. The matching problems in case of indivisible demand have been formulated as generalized assignment or multiple knapsack problems, which require solution of NP-Hard optimization problems. In this work we investigate the problem of matching under different types of constraints. The main contributions are as follows.

(1) We formulate matching problem as nonlinear integer programming problem and develop set of new results, which form the basis of our algorithm.
(2) We develop two algorithms to obtain optimum assignments of bids and asks in case of different types of constraints like assignment and indivisibility constraints.
(3) We show that our algorithms always obtain optimum assignment with polynomial time complexity.
(4) We then develop algorithm to compute VCG Payoff from the optimum solution without solving set of optimization problems.
(5) A payment mechanism, which is efficient, budget balanced and individually
rational is designed. We also study the effect of changing bid price by buyer and set of buyers and its effects. It has also been shown that group of buyers cannot affect our system by changing their respective bid price. The gains of the buyers are always bounded.

We also study truthful double auctions under different types of constraints. In electronic auctions, property of incentive compatibility can be very important. Incentive compatibility ensures that truthful bidding is the dominant strategy. Other important properties in electronic auctions are Budget Balanced (BB) and Individually Rational (IR). The former ensures that auction does not run in loss, whereas later ensures voluntary participation. However these can be achieved only after sacrificing efficiency. In this chapter we consider double auctions under different types of constraints, where truthful bidding is the dominant strategy. We design a mechanism which is strategy proof, individually rational and budget balanced. Here it is assumed that buyers and sellers have their private valuations independent of each other. The buyers and sellers submit their respective bids and asks depending upon their respective private valuations. In this case a part of bid and ask is public information, remaining part is private. The main contributions in chapter are as follows.

1. We generalize multi unit double auction (MDA) mechanism to handle different types of constraints. It has been shown that mechanism is budget balanced, strategy proof and individually rational.

2. The bounds on efficiency loss have also been established. We further show that efficiency loss tends to 0 as number of buyers or sellers become large.

3. Then we have developed discriminatory mechanism. It has been shown that mechanism is budget balanced, strategy proof and individually rational. It has been shown that in this mechanism also efficiency loss is bounded and asymptotically goes to 0.

4. It has been shown that this mechanism is false-name-proof. It means that buyer cannot improve his gains by submitting bids with false identification. This property is very important property in electronic auctions. It has been shown that buyer does not have incentive to reduce the demand.

5. The conditions for the existence of desirable mechanism are also worked out. Then the case where, mechanism is strategy proof, individually rational and efficient but not budget balanced, is considered. We attempt to introduce participation fees to cover up deficit. The cases of efficiency loss are also worked out. This can be helpful in cases where demand is far excess of supply or vice versa.

Auction mechanism for privatization of state owned enterprises, a very important application of electronic auctions in many countries, in the financial domain has been studied in this thesis. Traditionally auction based mechanisms have been used for leasing of mining rights, bandwidth allocation etc. In this work, we consider different types of auctions, which can be used in financial domains for Initial Public Offering (IPO) of Government owned companies. We also consider the scenario with different types of constraints. The main contributions of this chapter are as follows.

1. We formulate an optimization problem that can handle single object multi unit auctions with different types of constraints. It has been shown that, some of the single
object multi unit auction formulations, which have been studied earlier are particular cases of our formulation.
(2) We derive new results to obtain optimum assignment. An algorithm, which computes the optimum solution, has been developed. The algorithm generates optimum solution with polynomial time complexity.
(3) We then develop algorithm to compute VCG Payoff from the optimum solution without solving set of optimization problems.
(4) Then we generalize uniform price mechanism to handle different types of constraints. It has been shown that our mechanism is efficient, strategy proof and individually rational.
(5) Then we worked out discriminatory mechanism. It has been shown that mechanism is efficient, strategy proof and individually rational.
(4) It has been shown that this mechanism is false-name-proof. It means that buyer cannot improve his gains by submitting bids with false identification. So this property is very important in electronic auctions. It has been buyer also does not have incentive to reduce the demand.