Auctioning of Link Capacity

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Abstract

The rapid growth of the Internet brings us two facts: increased requirements on large bandwidth and adequate supply of network resources by competitive network providers. New pricing mechanism is needed to satisfy both network users and providers by providing a fair and rational network usage mechanism. Auction is one of important ways for setting price according to demand and supply. How to introduce the auction into the network resource (e.g. link capacity) allocation is an interesting topic worth studying.

In this paper, we study the issues on the auction of link capacity. Based on the preliminary study, we propose a research topic regarding a self-regulating auction for intelligent bandwidth allocation routing for further discussion. We think the auction is one of potential approaches for fair and rational pricing over the networks. But it is necessary to introduce new mechanisms in order to apply it in the new network paradigm.

Keywords: Auction, Link Capacity, Bandwidth Allocation, Pricing, and Payment.

1 Introduction

With the rapid growth of the Internet, the requirements of large bandwidth for better quality of services are increased. Simultaneously, new technologies, such as optical fibres and wireless links make big bandwidth supply with low price possible. At the same time, high competition among network service providers gives users flexibility to customize their bandwidth requirements and contracts with potentially lower expenditure. They prefer dynamic bandwidth contract tailored according to practical needs [1]. On the other hand, the network service providers do their best to pursue the maximum profits. These facts raise an interest in dynamic bandwidth broker mechanism that can be flexibly applied to network resource allocation.

Auctions are one of the important ways for bandwidth allocation. They have such merits as simplicity to determine market price and efficiency to achieve best market value. The auctions are classified variously, e.g. open outcry or sealed bid, ascending or descending, single or multi-unit, etc. [2]. In order to apply auction mechanism into network link capacity, we need to analysis whether the traditional auction approaches are suitable for the new paradigm of network link capacity.

This paper aims to study the auction mechanism of link capacity. Our discussion starts from understanding the original demand of link capacity auctions, the classifications of auction methods, and some issues related to online auctions in the networks. Based on the preliminary study, we further propose a self-regulating auction mechanism for intelligent bandwidth allocation routing.

2 Existing problems

2.1 Requirements

As mentioned in the introduction, the demand for the auction of link capacity over the networks is increasing. From the network service providers' points of view, they are in pursuit of the best profits and the largest market shares. They are always expecting their network resources are fully used in order to achieve the highest revenue. On the other hand, the network users are expecting the best quality of service with the cheapest price. With the growth and popularity of mobile Internet, the users are more expecting a flexible pricing mechanism that can support their mobility. Both parties seek fair competition of the network resources with accepted efficiency.

Confronting the competition of link capacity over the networks from both the users and the providers, it is a necessity to propose an effective pricing mechanism that enables the users and the providers to achieve their demands. The auction mechanism is one of potential candidates. It provides a fair allocation approach for the network resources according to the usage restraint.

2.2 Classifications

In what follows, we will firstly introduce some famous auction types, as well as their pros and cons [5-7]. Then, we will classify the auction of link capacity into two types: offline auction and online auction.

2.2.1 Auction types

Some basic types of the auction are briefly introduced as follows. They are widely used and analyzed.

- Ascending auction: The price is successively raised until only one bidder remaining, and that bidder wins the object at the final price (either seller announce prices, or bidders call out prices themselves, or by having bids submitted electronically with the best current bid posted).

- Descending auction: The auctioneer starts at a very high price, and then lowers the price continuously. The first bidder who calls out that she will accept the current price wins the object at that price.

- Sealed bidding: Each bidder independently submits a single bid, without seeing others' bids, and the object is sold to the bidder who makes the highest bid. The winner may pay the bid either the highest ("first" price bid) or the second-highest bidder's bid ("second" price bid).

- Open bidding: The bids submitted are open to each bidder. They are placed up until a specified time at which the portion of bidding closes. The winner is the bidder who submits the highest bid.

English auction is one of the most familiar auctions today. It is also know as the open-outcry auction or the ascending-price auction. This kind auction can easily help the seller to win the highest price. Unlike the sealed bidding, its bidding transparency makes easier to gain the bidders' trust on the auction system security. While, the sealed bidding is good for protecting the bidder's privacy. This type of auction also suffers from some problems like the buyer must be present, the auction's format is complex, it is highly susceptible to rings. (Rings have the overall effect of lowering the winning bid through a way that a subset of bidders gathers together and agrees not to outbid each other.)

Dutch auction is an open and descending auction type. It is a special type of the auction designed to handle the case where a buyer wishes to buy a number of identical objects. The buyer should specify the maximum price and the number of objects. The sellers bid at or below that maximum price for the number of objects that they are interested in selling. At the end of auction, the lowest bidders earn the right to sell those objects at the minimum successful bid. Different from the English auction, the concept of reverse auction herein makes the seller as the bidder, while the buyer selects the lowest price. Thus, this type of auction benefits the buyer. However, in the Dutch system, if the buyer with the highest interest in the objects, he might make decision at or near his highest valuation.

2.2.2 Offline auction

The auction is conducted offline before network usage. It is similar to the traditional auction methods except that bid target is the link capacity of some indicated paths from one end to the other end. The traditional auction methods introduced above can be applied into the offline auctions. But this static, long-term contract cannot satisfy today's requirements from both the users and the service providers in order to achieve their expected profits.

2.2.3 Online auction

The auction is conducted online in the networks in order to reserve preferred link bandwidth for a short term. This customized bandwidth contract raises special interest recently. It has advantages that the price of the link capacity can reach the best based on the market demands. It also provides flexibility for the users to find the best route as soon as possible if they are willing to pay for it. With this mechanism, the Quality of Service may link together with the price. In addition, it helps the rational management of the network resources. In this paper, we focus our discussion on the online auction.

It is expected that the price of high-demand link is high while the price of low-demand link is low. But the challenge of the online auction lies in it is meaningless for the users to auction only one link while their aim is to set up a path from the source node to the destination node. The path is composed of a sequence of links with different demands and different capacity, as shown in Figure 1. This raises a series of issues regarding the online auction.

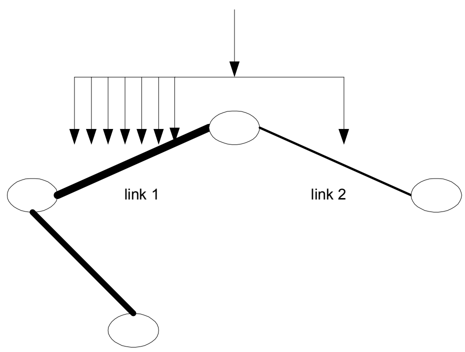

Figure 1: Different demand and capacity

Old auction methods may not applicable in the new paradigm of the network. For example, simple use of either ascending or descending auction cannot fit the dynamic change of the demand and supply for the link capacity. Thus it cannot reflect the real market price. We need reexamine the old auction approaches for the new requirements. They should be further improved or hybrid-used in order to fit into digital processing in the networking.

2.3 Issues

As can be seen from the above, we lack an auction-based self-regulating, efficient and fair mechanism for link capacity allocation in a network. In order to conduct research on above on-line dynamic auction of link capacity, we need to seriously consider some important issues as described below.

- Auction model

It is a necessity to design a suitable auction model that can satisfy the business requirements of both the users and the providers. The auction model provides a dedicated research background by concretizing the network environment. It also clarifies the problems that the underlying auction mechanism solves. A suitable model will benefit researchers to concentrate on the special auction mechanism on special issues. For example, in [1], it is assumed that the user requests the same bandwidth on each link of a path and has the ability to pay for the auctioned capacity once wining, as shown in Figure 2. Each user independently decides the quantity of bandwidth in a path worth to him. The price is based on unit bandwidth, and so on. The network topology is also an important component of the auction model.

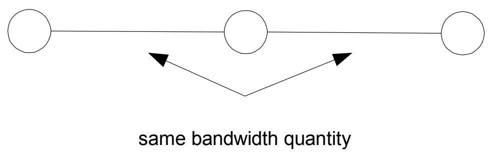

Figure 2: User's objective

- Price rules of auction

The price rules of auction greatly affect the success of a self-regulating auction mechanism. The price can be increased or decreased from the initial price according to different algorithms. The price's increasing or decreasing could also be dynamically selected during the auction at different time period.

- Payment rules of auction

The payment rules are also very important because they affect the user's (bidder) behavior and strategies, thus determining the auction outcome. In addition, it influences the provider's revenue and the efficiency of the auction systems.

- User auction strategies

The users strategies determine the users' bid and acceptance of the price and payment. The strategies are influenced by the users' link capacity demand, willing of total payment, maximum/minimum payment on each link, as well as other factors.

- Provider auction strategies

The provider's strategies decide the initial price of the auction and price update policies. Generally, the strategies are driven by the supplier's market requirements dynamically.

- Performance evaluation rules

The performance evaluation rules are used for evaluating the performance of the auction mechanism applied. At present, people pay more attention to the provider's welfare, which involves the revenue, the usage percentage of bandwidth resources, and the market share, etc. In our opinion, the evaluation rules should concern two aspects. One aspect is regarding the performance evaluation rule for the providers. The expected goal decides the provider's auction strategies, which will further affect the pricing rules and the payment rules. The other aspect is about the evaluation rules for the users. Some factors, such as expenditure and efficiency, should be considered by the users to examine their auction strategies.

In the auction model defined study environment, the relationship of different issues can be illustrated in Figure 3. It is essential to consider all the issues and their cooperation in order to provide a good solution for the link capacity auction in the networks.

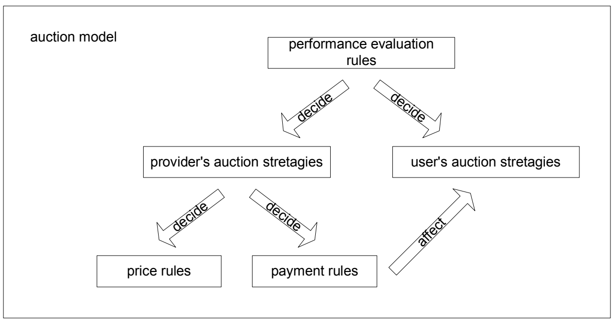

Figure 3: Relationship of auction issues

3 Related work

The work on auctioning of link capacity is still in its infancy. The studied auction model is still quite simple.

In [1], a simple and efficient auction (MIDAS) for allocating bandwidth on a network basis to users is developed. It is assumed that the users wish to utilize the bandwidth for the same time period. The MIDAS consists of a set of simultaneous multi-unit Dutch auctions, one per link. It is expected for the users to simultaneously bid for the quantity demanded at all relevant auctions in order to immediately allocate bandwidth. The bidders' strategies are based on the feedback on spare capacities and prices. A special feature of the MIDAS is the prices at various links are reduced at different rate for reflecting the different demand at different links. According to the experimental evaluation of two price reduction policies, the authors argued the efficiency of the mechanism in terms of social welfare associated with the resulting bandwidth allocation.

The authors have proved that it is impossible to synchronize the auctions of various links due to the demand difference per link if employing ascending auctions. Therefore, this work considers the issues of pricing rules by descending price in two ways.

- Variable reduction rates (VRR)

This price policy contains a decrement rate of the per unit price of bandwidth per link, at any time *t*, the price at link *l* is given by the equation:

$P_l(t) = p_l(t-1) - max\{[C_{spare}(t;l) / C_{init}(l)] * MaxDrop, 1\}$

This equation reflects the demand. The decrement rate of link *l* at time *t* is proportional to the fraction of the current spare capacity $C_{spare}(t;l)$ divided by its initial value $C_{spare}(t;l)$. The price at each link is reduced at every step at least by 1 and at most by *MaxDrop*.

- Price freezing policy (PF)

Based on this policy, the prices are reduced constantly at a fixed rate *r*. The price is frozen for some time that is proportional to the quantity *x* of the bandwidth just allocated in the link. The freezing period equals *f*x*, where *f* is a constant expressed in time units per bandwidth unit. If additional allocations occur during the period of freezing, then the price will keep frozen for more time accordingly. When the price in a link *l* is not frozen, there is

$P_l(t) = p_l(0) - r\,[t - f\,x_l(t)]$

Where $P_l(t)$ is the price per unit of bandwidth in link l at time t, $P_l(0)$ is the initial price. $x_l(t)$ is the total quantity of bandwidth allocated at link *l* by time *t*. Obviously, values of *f* and *r* influence the pace of the auction. This equation also reflects an explicit relation between the price and the spare capacity of each link.

The payment rule applied in [1] is stop-out pricing. That is each bidder is charged per link for the unit price of the last winning bid for this link. The charge is independent of player's bid, unless the bidder is the last. It is analyzed that this rule is almost incentive compatible for guaranteed players, with limited incentive for bid shading. Instead, a simple payment rule, pay-your-bid has such a problem that it leads to bid-shading. It is proved that the bid-shading may result in inefficiency, because this rule affects the users' incentive for honest revelation of their valuations.

The existing study on the auctioning of link capacity is still based on the simple auction models. But the network topology and capacity relationship are quite complicated. We are still lacking a common self-regulating auction mechanism to manage and maintain the network resource that could benefit both the providers and the users in various scenarios.

Unfortunately, this work does not consider applying the reduction auction mechanism into the real networking mechanism, such as routing. It only considers the descending auction, therefore it cannot satisfy the dynamic change of demand and supply for the network resources in the networking. It is not a real self-regulating auction that has been approved to be deployed in practice.

4 Proposal

4.1 A proposal

Based on the above study, we propose a research topic for further discussion. We think it is worth studying on the self-regulating auction for intelligent routing in terms of the bandwidth allocation. The auction mechanism is helpful for the users to gain priority at the high demand links and save expenditure if the demand is low. It is also beneficial for the providers to gain as high as possible revenue in a fair competitive environment. Thus it will contribute to the routing intelligence on link capacity as one of the most important aspects.

We suggest establishing a policy based automatic auction mechanism at the network decision point for intelligent network resources allocation. A proposed system structure is shown in Figure 4. An auction manager (AM) is located at each resource decision point (e.g. a router or a gateway) in the networks. It connects with a network manager (NM) for the resource allocation checking, reporting and billing. It also checks with the providers' auction strategies engine (PASE) to decide price rules and payment rules. The network users have an auction bidder (UAB) with them as a digital bidder and a resource requestor. The UAB can be embedded into routing mechanism for the bandwidth (resource) auction. The network manager (NM) can be local, domain based or centralized. The NM is responsible for auction strategies evaluation, billing generation and network resource management.

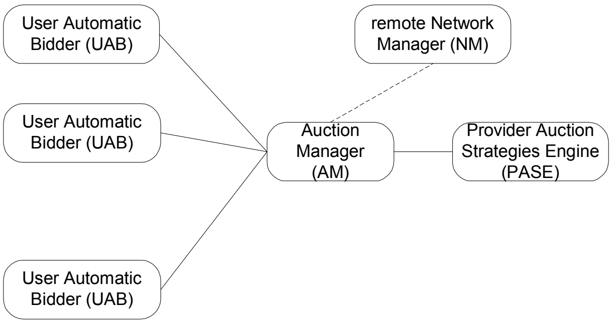

Figure 4: Auction structure

Further, we draft an auction processing procedure as depicted in Figure 5 based on the structure proposed above. This procedure supports dynamic pricing/payment rules according to the provider's strategies. While the strategies themselves are affected by the demand analysis. In this way, both increasing auction and decreasing can be applied and replaced with each other if necessary.

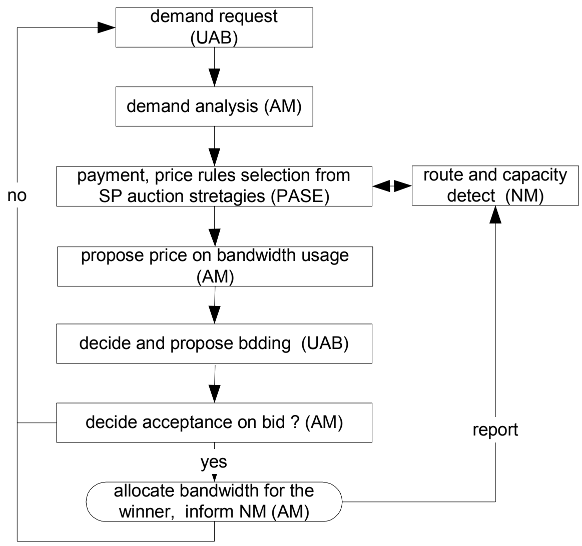

Figure 5: Auction procedure

The purpose of this proposal is for further discussion. It is very interesting to know if this topic is

- worth studying
- significant for intelligent network resource management
- beneficial for both the users and providers

practical to be embedded into network routing and other mechanisms that are related to bandwidth allocation

4.2 Other important issues

Further considering the above proposal, we find other important issues worth paying attention to.

- Trust billing

The auction billing and charging are taken charged by the network manager. It can be located locally or remotely. Obviously, it is most possible that multiple NMs will exist in the networks. But the billing report from one auction manager only goes to its registered NM. This causes a problem regarding how to generate a trust bill for the network users according to the reports from different NMs in terms of the same user. Attacks such as impersonations and replaying are potential threats.

- Routing Embedment

We think it is easier to embed the auction mechanism into on-demand routing protocols, while it is difficult to use it in table driven routing. The *table-driven* or *proactive* protocols require the periodical refreshing or updating of the routing information so that every node can operate with consistent and up-to-date routing tables. The advantage of the proactive approach is that once a route is formed, its use is efficient. But the pure proactive protocols do not suite heavy link capacity information exchange. *Source-initiated on-demand driven* or *reactive* protocols, in contrary, do not periodically update the routing information - the data is propagated to the necessary nodes only when necessary. It is easy for us to embed the proposed procedure shown in Figure 5 into the routing request process. The disadvantage of the reactive protocols is that they create a lot of overhead when the route is being determined. Both embedding may raise a problem regarding the efficiency. Thus, the performance of the auction on link capacity involved routing becomes an important issue to study in terms of practice.

5 Conclusions

In this paper, we studied the motivation of network auction for link capacity. Based on the analysis of original requirements and important issues, we studied a related work on network auction pricing and payment. Furthermore, we tried to propose a research topic regarding self-regulating auction for intelligent network resource allocation. As initiation, we provide a network auction structure and an auction procedure for further discussion on the significance of this work.

Price is one of the crucial drivers of network services. A fair and rational pricing mechanism is welcome by both the network providers and the users. It is also being expected this mechanism can be automatically applied into any places regarding network resource allocation with effectivity and efficiency. The auctioning of link capacity is one of interesting topics worth our attention. It is also necessary reexamine the traditional auction approaches in order to use it in the new network paradigm.

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