Online Auction Site Management

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OUTLINE

GLOSSARY

Activity Rules: Rules that constrain a bidder's options based on her actions in previous rounds of the auction.

Auction: A system for accepting bids from participants and computing a set of trades based on the offers according to a well-defined policy.

Auditable: An auction system that can be inspected by an outside auditor to confirm that the auction's actions were in accordance with its policies and the bids received.

Beat-the-quote Rule: A rule that requires the bidder's new offer to improve upon her current offer with respect to the current quote information.

Bid: An offer to buy or sell a product or service submitted to an auction.

Bid Admission: The act of certifying that a bid satisfies the bidding rules and has become an active bid in the system.

Bid Schedule: An offer that specifies a desire to buy or sell at more than one price point.

Bid Submission Time: The time at which the auction officially considers the bid submitted.

Clear: The act of computing trades in accordance with the auction's policy, and removing the associated bids from the set of active bids.

Combinatorial Auction: An auction that allows bidders to make offers on combinations of items.

Consistent: An auction system that handles all bid, quote, and clear events in the order they ought to occur.

Content Management System: A Web publishing tool that facilitates the management and presentation of large amounts of content on the Web.

Double-sided Auction: An auction with multiple buyers and sellers.

Improve-your-bid: A rule that requires a bidders' new offer to improve upon her previous bid in a precise manner.

Matching Function: The policy the auction uses to compute trades from bids.

Multiple Bidding: A strategy involving a fake bid placed by a buyer with a secondary account to scare off other buyers. The high bidder then defaults on the bid and the real buyer wins with less competition.

Order Book: The list of current bids and the bidders who placed them.

Parallel Architecture: An auction architecture that, to some degree, allows multiple actions to be handled simultaneously.

Proxy Bidding: The use of a software program to place bids on behalf of the user. A proxy bidder, unlike an agent, is generally operated by the auction.

Quote: The activity of computing and announcing information about the current state of the auction; the information computed and announced.

Reputation System: A system that allows a community of traders to comment on each others performance, thus enabling users to establish reputations within the community.

Reserve Price: In a single-seller auction, the minimum price at which the seller is willing to part with the item. In a single-buyer auction, the maximum price the buyer is willing to pay.

Sealed Bid: An auction in which no information is revealed until the auction closes and the winners are announced.

Sequential Architecture: An auction architecture that performs one action completely before beginning another.

Shill Bid: A fake bid placed by a seller, or his collaborator, to raise the price paid by real buyers.

Single-sided Auction: An auction with either a single buyer (and multiple sellers), or a single seller (and multiple buyers).

Trade: A declaration by the auction that one bidder should exchange a particular quantity of the item with another bidder at a particular price. Generally, the execution of the trade is outside the scope of control of the auction system.

Valid Bid: A bid that satisfies the bidding rules.

ABSTRACT

The successful deployment and operation of an online auction system requires knowledge of mechanism design, system architecture, and successful Internet business practices. Online auctions pose several challenges to Web developers because they are intensely data driven and have temporal behaviors that must be faithfully implemented. This article discusses many of the issues that an auction provider should consider when selecting or developing an auction software system. Auctions can be seen as a mechanism that is precisely defined by sets of rules that govern bidding, quoting, and clearing. These activities will have natural components in the software system, and the choices made in the architecture of the auction system will affect its scalability, temporal integrity, and overall complexity. Complementary features of auction systems, such as catalogs, search tools, and reputation mechanisms, are also discussed.

INTRODUCTION

Internet auctions appeared on the scene in the mid 1990s, and quickly became one of the most successful applications of electronic commerce. EBay, the premier consumer-to-consumer (C2C) Internet auction site, is generally held up as an exemplar for the industry. However, it is widely predicted that the potential transaction volume in business-to-business (B2B) auctions will be much greater than in the C2C channel (Keenan, 2000; Rosenthal, 2002).

In the B2B marketplace, auctions were initially pressed into service as tools to dispense with excess inventory. One-time market leaders like Onsale[1] helped companies, primarily consumer electronics manufacturers, sell products near the end of their lifecycle. The current wave of B2B integration represents a much deeper integration of auction technology into the day-to-day operations of many businesses. In particular, companies are using auctions in many procurement situations in an effort to extract better prices from their suppliers. This move toward more formal and rigorous negotiation with suppliers folds neatly into the need to better manage the supply chain and make operations more efficient. The third wave of integration will involve the use of dynamic pricing through the entire product lifecycle, on both the sales and procurement sides. We are already starting to see evidence that products are being sold by auction earlier in their lifecycles; IBM and Sun regularly sell relatively new products via a distribution channel on eBay.

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[1] Onsale was founded in 1996 and made a name for itself early on as an auction-based outlet store. Eventually, they added a C2C component in an attempt to better compete with eBay. In what now seems like the prototypical dot.com arc, Onsale merged with Egghead in 1999, and the combined company filed for bankruptcy in 2001.

Though eBay sets the standard for features and performance in C2C markets, the potential applications of auctions to B2B markets requires more varied and complex systems, and places different burdens on the auction administrators. On the one hand, B2B auctions may require more elaborate and sophisticated auction processes, such as combinatorial auctions (Rothkopf, 1998). On the other hand, B2B markets tend to have well known and authenticated bidders and lower overall communication loads.

Auction systems have three distinct sets of users: the bidders, the auction initiator, and the auction system administrator. Each class of users requires different core and complementary features of an auction system. Note that we do not treat sellers and buyers separately; in the general case they are both bidders and have the same needs. On most consumer-to-consumer sites, the seller is the auction initiator, and places his one and only bid, to establish the reserve price, during the creation of the auction, if at all. The auction system administrator is the person (or group of people) who installs, configures, and maintains the auction site.

This article discusses many of the issues related to Internet auctions for B2B, B2C, and C2C marketplaces. The discussion is framed by a brief history of auctions on the Internet, followed by an introduction to some central concepts. The rest of the article is divided into two parts: a description of the core features of auction systems, followed by a discussion of features that are complementary and commonly impact the design or selection of an auction system.

BRIEF HISTORY OF INTERNET AUCTIONS

It is difficult to pinpoint the earliest auction held on the Internet, but it is clear that auctions were conducted via e-mails and newsgroups as early as 1988.[2] As the Web developed in the early 1990s, it was only a matter of time before people began using this new technology to enhance their online auctions. At first, sellers simply provided a static source of multimedia information (i.e., text and images) about the products being auctioned and continued to collect bids via e-mail. Later, sellers used Web forms to actually collect and process bids. EBay, founded in 1995, was among the earliest known auction services available on the Internet. However, within a year eBay had many competitors, including uBid, Onsale, Z-auctions,[3] and more. In the B2B arena, Fastparts.com was an early market maker, having bulletin board based systems as early as 1991, and launching a Web-based system around 1996.[4] Internet auction platforms were also being developed in research laboratories in 1996, including the Michigan Internet AuctionBot (Wurman, Wellman, and Walsh, 1998), the FishMarket system (Rodriguez, Noriega, Sierra, and Padget, 1997), and GEM (Reich and Ben-Shaul, 1998).

The need to rapidly build hundreds of electronic auction sites in a wide variety of industries created opportunities for packaged and hosted software systems. In order to satisfy the demand, several companies built and marketed auction software. Among the best known of the auction service providers were OpenSite, Trading Dynamics, Moai, and FreeMarkets. FreeMarkets was founded in 1995 and Moai formed in 1996. OpenSite began life as Web Ducks, Inc. around the same time, while Trading Dynamics was founded in 1998. OpenSite and Trading Dynamics were

[2] See the historical record (formerly called deja-news) at http://groups.google.com/
[3] Now defunct.
[4] Information from http://www.fastparts.com/fpwebsite/jsp/about/about.jsp.

acquired in 2000 by, respectively, Siebel Systems and Ariba. Around the same time, IBM was building its own auction engine (Kumar and Feldman, 1998), and CommerceOne acquired CommerceBid to obtain auction technology. Moai and FreeMarkets both remain independent companies. Though these more established companies remain the leaders, the field has become crowded with new ventures, such as i2, ProcureNet, Frictionless, and ICG Commerce, and procurement solutions introduced by multinational companies like SAP, General Electric, and IBM.

In the early days of e-commerce, it was logical for auction software companies to design flexibility into their products so that they could be employed in many application markets. Thus, these products are typically designed to allow customization, to some degree. The amount and type of customization depends on the particular details of the target market, and whether the auction engine was slanted more towards B2B, B2C, or C2C applications. Today, most major e-commerce vendors have an auction product targeted at B2B procurement, though these products vary widely in features and customizability.

More recently, there has been growing interest in advanced auction formats. These advanced formats include *combinatorial* auctions–auctions that allow bidders to place offers on sets of items. Several companies have recently begun offering systems that manage combinatorial trading.[5] Another type of advanced auction that is starting to appear in electronic systems is the multi-attribute auction, in which the object (or contract) being negotiated has several negotiable parameters in addition to price. An oft-cited example is a negotiation between

[5] CombineNet, Emptoris, NetExchange, and TradeExtensions are among the leaders in commercial combinatorial auction systems.

a manufacturer and a supplier in which product quality (or purity) and delivery date are negotiable. In a multi-attribute auction, different suppliers will offer contracts that differ in the promised product quality or delivery schedule, and the buyer needs a well-defined method for selecting among the contracts and (optionally) generating the equivalent of price quotes.

It is also important to note that Internet auctions were not the first auctions facilitated by electronic networks. NASDAQ's Small Order Execution System^SM began operation in 1984, and many of the stock exchanges now incorporate electronic trading or electronic support systems. Historically, financial systems ran on closed networks, with custom trading stations at designated, access-controlled locations. Operating markets on the public networks raises new concerns, such as security, privacy, identify verification, and network availability. In addition, the much wider variety of products and services being negotiated on the Internet requires versatile trading systems.

AUCTION CONCEPTS

Although the term auctions tends to bring to mind the classic situation with a seller offering a single item to the highest bidder, like eBay or the stereotypical face-to-face auction, the accepted definition of the term in economics includes a wide variety of negotiation mechanisms. The English auction, procurement auctions, and stock markets are members of a large class of negotiation mechanisms that can rightly be called auctions, and can be precisely defined by their rules. It is useful to collect the rules into three related sets: rules that govern the admission of bids, rules that govern the information revealed by the auction, and rules that govern how the auction computes trades. A detailed mathematical treatment of these rules is available elsewhere

(Wurman, Wellman, and Walsh, 2001).   Of concern here is how the parametrization affects the choice of an auction system.

Flexible auction systems are built around some notion of parametrization, though most auction systems have simplified interfaces that make it easy to implement common configurations. For example, an auction initiator can simply select "English auction" to get a standard ascending auction rather than go through the potentially confusing task of specifying the bidding rules and quote and clear policies that define the English auction.

Bidding rules

Bidding rules define the types of bids that are allowed and which participants are allowed to place them. In a single seller auction, the designated seller is the only participant who can place a sell offer, and is typically required to do so at the beginning of the auction. If that offer is non-zero, then the seller's offer is called her *reserve price.* In a procurement situation, only the designated procurer can place a buy offer, and typically, the members of a pre-screened set of suppliers are the only participants who can place sell offers. In an open, Continuous Double Auction (CDA), like the stock market, any participant can place either a buy or sell offer.   In fact, in a CDA, a bidder can simultaneously place offers to buy and sell, as long as the buy offers are less than the sell offers. Much of the flexibility of auction systems comes from treating buyers and sellers symmetrically.

Different auction mechanisms may have different languages for expressing the bids. The simplest type of bid is an offer to buy or sell one unit at a specified price. When multiple units are being traded, the language may allow the bidder to express a *bid schedule* in which the buyer (seller) expresses how many units she would like to buy (sell) at various prices. This allows a bidder to, for instance, say "I'll buy one unit if the price is less than $50 and two units only if the price is $35 or less." A language that allows multi-unit bids must have clear semantics. In particular, it must be clear whether the auction has the right to partially satisfy the bids. For example, the statement "I'll buy two units if the price is less than $25," can be interpreted as "I'll buy exactly zero or two units if the price is less than $25" or "I'll buy zero, one, or two units if the price is less than $25." In the latter case, the bid can be partially satisfied, while in the former case it cannot. When bids cannot be partially satisfied, the auction's clearing and quote generation tasks may become computationally intractable.

In combinatorial or multi-attribute settings, bidding languages can become even more complex, and the ability to express bids concisely becomes an issue (Nisan, 2000). Moreover, the auction designer can choose among several rules that restrict bids as a function of the current price quote or of the bidder's previous offers. The *beat-the-quote* rule requires that a new bid be better than the price information revealed by the auction. In the English auction, the interpretation of the beat-the-quote rule is obvious and simple to implement. However, in advanced auctions, the rule can be subtle to interpret and apply, and does not always achieve the desired outcome of progressing the auction. The *improve-your-bid* rule is an alternative that requires that a bidder's new bid be a strict improvement over her previous bid. Although not obviously useful in an English auction, in advanced auctions the auctioneer will often need to use the improve-your-bid rule in conjunction with the beat-the-quote rule to achieve the desired results. Ausubel and Milgrom (2002) propose a combinatorial auction in which the improve-your-bid rule is the *only* bid improvement rule.

Recently, market designers have started using *activity rules* to determine what types of bids are permitted. Like the improve-your-bid rule, activity rules define allowable new bids based upon the bidder's previous bid state. Activity rules condition the allowable bids on a variety of measures of previous activity, such as the number of objects the bidder was winning, or the number of improved offers that were made in the last bid. The discussions that surround the government auctions for spectrum licenses focus, to a large extent, on the selection of activity rules that encourage progress without over-constraining the bidders (McAfee and McMillan, 1996).

In addition to controlling the *who* and *how* of bidding, the rules control the *when*. In simple scenarios, bids are accepted at any time. However, some auctions are organized into timed rounds, while others require an offer from each designated participant before they can progress.

Intermediate Information

Auctions that generate no intermediate price information are called *sealed-bid* auctions. However, the vast majority of online auctions generate intermediate information to help guide the bidders. Typically, the information generated is a current price, often presented in the form of a *bid-ask* spread. Although the bid-ask concept is inspired from the stock market–a continuous double auction in which the buyers and sellers offers do not overlap–these concepts can be generalized to a larger class of auctions (Wurman, Walsh, and Wellman, 1998). In addition to price information, an auction may reveal a list of the current bids–called an *order-book*–or the identities of the bidders.

Price information becomes more complex to compute and express with advanced auctions. For instance, in multi-unit auctions that allow bidders to make all-or-none offers, a simple price-per-unit announcement may not accurately inform the bidders whether they are currently winning the auction. In fact, an all-or-none offer may be turned down in favor of an offer that has a lower per-unit value because the overall value of the trades is greater. For example, an auction in which the seller is offering three items may choose a bid to buy exactly two items at $4 each, and a bid to buy one item for $2, and not select an offer to buy exactly two units at $3 each. The former two bids generate $10 of revenue for the seller, and no combination using the third bid can do as well. Most C2C auctions finesse the problem by listing the current undominated bids and whether they are winning, instead of announcing prices. It is left up to the bidder to compute what bid they would have to place to become a winner, or to simply improve their bid and observe the effect.

Clearing

The final collection of rules determines when and how an auction computes trades. The act of computing trades is called *clearing,* and is handled by a well-defined policy instantiated as an algorithm in the auction software. An auction may clear whenever a bid is received (i.e., continuous clearing), when no new bids are received for a specified time (e.g., the typical English auction), at a prescribed fixed time (e.g., eBay) or on a prescribed schedule. The policy that is used to compute trades we generically call the *matching function.* There are many different types of matching functions, some of which are described in the companion article on Online Auctions (Anders, this volume). The various matching functions trade off desirable properties that cannot be simultaneously achieved even when a single item is being sold by a seller to a single buyer. In combinatorial scenarios, the tradeoffs are more complex, and are further influenced by computational factors.

THE CORE OF AN AUCTION SYSTEM

The rules discussed above suggest a generic architecture which delegates the responsibilities of the three main rule sets to corresponding components of the architecture. Although specific auction systems will vary in their actual software architecture, most can be abstracted into the generic software architecture shown in Figure 1.

<< Insert figure 1 here. A model auction architecture. >>

The diagram illustrates some of the core interactions that bidders and initiators have with an auction system, and some of the primary internal procedures. In actual commercial systems, the internal components may be more or less clearly delineated than in the figure, but the responsibilities remain essentially the same. Industrial strength databases are used to store information about the auctions, bids, users, and transactions. The use of a database ensures data reliability and facilitates the communication of data between the disparate components of the system. Although clearly beneficial, adding a database also adds significant computational overhead, and communicating with it is often a performance bottleneck.

An auction is created when a user (the initiator) interacts with the *auction manager* to specify and launch a new auction. Auction creation can be a time-consuming process. The initiator must clearly describe the product, including as much detail as necessary for bidders to know exactly what they are buying or selling. Often the product description will also contain information about the shipping and handling, payment process, and other details pertinent to the transaction. In B2B procurement scenarios, the process is even more onerous, and many procurers soon realize that they have to generate very precise definitions of the products and the contractual obligations before the suppliers will have the information they need to bid properly. Occasionally, the initiator will need to clarify information during the course of the auction. Generally, updates should augment, rather than replace, the original text, and bidders who placed bids before the update should have the option of retracting their bids if the description has changed dramatically.

The initiator must also select the rules of the auction, and choose key parameters such as the duration, bid increments, and format of the bids. In many B2B scenarios, the initiator will specify the set of bidders that are permitted to participate in the auction.

The *bid manager* component is responsible for enforcing the bidding rules and admitting bids that satisfy them into the system. To enforce some types of bidding rules, the bid manager may have to extract the auction description and current state from the database. For instance, to enforce the beat-the-quote rule, the bid manager needs to extract the auction's current quote information, while to enforce the beat-your-bid rule the auction must extract the bidder's previous bid. Once the bid manager has determined that a bid satisfies the conditions, it *admits* it into the set of current bids and stores it in the database. Bids that are admitted are termed *valid*, while those that are not admitted are *rejected.*

The *clear manager* is responsible for executing clear actions. It must read the bids and the auction's configuration from the database and compute *trades* according to the auction's policies. The new trades are stored in the trade database. In addition, information about the bids and the auction may have to be updated in their respective databases. For example, a bid that becomes part of a trade needs to be marked as transacted in the bid database.

The *quote manager* is responsible for generating price or other information about the auction in accordance with the auction's policies. The quote manager may update the bid database in order to track which bids are currently winning, and may store new quote information as part of the auction database. Both the quote manager and the clear manager must communicate the results of their actions with the interested parties, as indicated by the arrows in the figure.

Scheduling Actions

Not shown in Figure 1 is a system for triggering the actions and coordinating the activities of the various components. A critical feature of an auction system is its ability to guarantee the proper sequencing of actions. For example, if a bid is received one second before a clear event, the bid should be considered when the clear is computed. If two bids are received nearly simultaneously, the first bid should be handled before the second or an incorrect trade may result. An auction system that provides a guarantee that events are handled in correct chronological order is *consistent* and *auditable*–if an external auditor looked at the bids after the auction was over, she would be able to show that the auction did the right thing. Often, these demands conflict with the desire to make the system perform in real time. Different systems handle this complicated tradeoff differently.

One method of guaranteeing consistency is to have a *sequential* system. In a sequential system, there is only one thread of control for a given auction, thus guaranteeing that events happen in the correct order. However, a sequential system cannot handle a new event until it has finished processing the previous one; it cannot accept a new bid while it is generating a price quote or admitting a previous bid. If any of the events take a noticeable amount of time to compute, the system will appear to be unresponsive, or unavailable for other uses. A sequential system also does not benefit from the advantages of multi-threaded processing, such as improved use of processor and I/O resources.

A *parallel* auction system can handle many auction events simultaneously, but greater care must be taken to ensure that the events are handled in the correct order. It is relatively straightforward for the auction program to correctly sequence the quote and clear activities when they are internally triggered, but when they are triggered by the asynchronous submission of bids, sequencing is more difficult, The *bid submission time*---the point at which the bid is officially considered admitted---is a key design element of the system. Essentially, there are three choices, corresponding to points at which the bid is *spoken*, *heard*, and *understood*. These points are labeled (1), (2), and (3) in Figure 1.

Users would like the bid submission time to be the moment when they click the submit button on a Web form (1); this is problematic for a number of reasons, including the fact that the submission time is measured by the local machine whose clock cannot be verified by the server. The second choice is to stamp a submission time on the bid when it reaches the server (2). In this case, all the bids can be tagged with a central clock, and the server's response to the user can state that the bid is officially submitted but has not been validated by the bid manager. In addition, the system must be designed so that clears and quotes wait until the bid manager has actually validated all of the submitted bids, introducing a level of asynchrony into the system (Wurman, Wellman, and Walsh, 1999). The third choice is to consider the bid submitted only after it has been validated by the bid manager (3). The advantage is that a definitive response regarding the admission of the bid can be returned to the user. However, in many cases validation requires a call to the database, and therefore takes time. In advanced auctions, the evaluation of a bid's validity may be computationally complex, and the response back to the bidder must be delayed until this computation is complete.

Some auction systems relax the guarantee regarding the admission of bids for some types of events. For example, at the time of this writing, eBay's system does not guarantee that its beat-the-quote rule is enforced for bids received within a very small window of time. While examining the data, we have found cases in which a bid was admitted with a time stamp that is one second after a bid that would have made the former bid rejected (Shah, Joshi, and Wurman, 2002). However, presumably due to the asynchrony, the earlier bid had not been fully processed and the new minimum bid computed when the later bid was admitted. Although eBay relaxes the temporal ordering while processing two competing bids, it does not do so when processing the clear event.

These issues become more complicated when the auction system is distributed over several hardware devices. Like other 3-tier architectures, auction systems can rely on a database that resides on another machine. Many auction systems also benefit from the fact that the auctions themselves are independent of one another. This enables, for instance, all auctions related to product 1 to be stored in a database on machine A, while all auctions related to product 2 to be stored in the database on machine B. The ability of the auction software to be distributed in this way goes a long way towards making the system *scalable*. As in other distributed architectures, load balancing becomes an issue. The issues of effective load balancing in auction systems have not been carefully addressed in the literature on auctions.[6]

Notification

Figure 1 suggests that information flows out of the auction system to the users in the form of price quotes or information about trades. In the early days of auction systems, participants received up-to-date information either through text-based e-mail or by checking the Web site. These two methods represent two quite different approaches to the communication process. E-mail based notification is a *push* technology, that is, when information changes, the server pushes the new information to the clients. Web-based dissemination is a *pull* technology, and clients must explicitly request the latest information from the server. Even as auction systems are increasingly connected to more mobile information devices (eBay can send notifications to e-mail enabled mobile phones, pagers, and PDAs), the push-pull distinction still divides the multiplicity of communication channels.

Whether an auction system uses push or pull technology, or both, depends upon the application, but the two formats put different stresses on the architecture. In a push system, users

[6] Interestingly, markets have themselves been promoted as solutions to load balancing problems (Clearwater, 1996). Essentially, the machines in the cluster auction their time; the busier a machine is, the more expensive its time becomes.

will typically subscribe to various types of notifications. Each time an event occurs for which some people have requested notification, the server must compose and send a message. In some settings, this process may generate more messages than are needed to keep the users informed. For instance, if I am away from my computer for a while, when I log back on I may not need to know all of the intervening price changes, but only the most recent.

Pull-based communication does away with the excess of information, but may introduce and excess of information-less messages. In a pull system, a user requests information only when she is ready to look at it. However, because she doesn't know whether the information has changed on the server, she will be forced to make frequent requests to keep her information up to date, and the majority of those requests have no new content. Thus, when users need very up-to-date information (e.g., at the very end of an eBay auction), they will make frequent requests to the server and can easily overwhelm the system. This may be true even when push-based information is provided because push channels–like e-mail–are generally asynchronous themselves and don't provide the most up-to-date information.

There are several approaches to controlling the load placed on the server by information requests. One method is to cache the information in files (or memory) so that it can be served quickly. This method is very successful for content-oriented sites, but can be problematic for dynamic sites like auctions. EBay's category listings are emblematic of the difficulty of keeping all views of an auction up-to-date. The category listings are not refreshed in real time, and it is very common to follow a link from the catalog to the auction description and find that the current price is much higher than the price listed on the catalog, especially near the end of the auction.

A system architect's alternative to caching the catalogs is to generate them on demand, an approach that would be untenable given the number of user requests and the number of database queries involved on a site like eBay, but which may be practical for smaller sites.

Scaling

Like any Web system, the hardware and software architecture has to be scaled to handle the expected load. An auction site manager should be concerned with at least three types of loads: *page views*, *bidding actions*, and *internal actions* like clears and quotes. Page views measure the number of requests for HTML documents from the clients. Static pages can be served faster than dynamic pages (which require calls to a database). Unfortunately, auctions are highly data-driven sites, and many of the pages, like the auction status, must be constructed on the fly. Bidding actions put an extra strain on the system because writing to a database is slower than reading from one, and temporarily locks others out. Thus, the load due to bidding should be considered separately from that due to page views. Finally, the events triggered internally compete for computational resources, and steps must be taken to minimize negative effects from concurrent internal events.

In order to properly scale the system, it is necessary to estimate the loads. This can be done easily from an estimate of the number of auctions hosted and educated guesses about the behavior of the users. For example, if a C2C auction site hosts x auctions per time period t, and we expect an average of b bidders each with r bids per auction, we immediately have the expected number of bids, brx/t. To get an estimate of the number of page views, suppose that the seller and bidders track the auction by viewing the auction description v times each. The number of page views due to this activity will be $vx(b+1)/t$. In addition, bidders will look at n auctions before selecting one in which to bid. Thus, we would expect an additional nb/t page views due to searching. It is relatively easy to estimate some of these parameters by examining bidding patterns on existing sites like eBay. These calculations return an average load. A system administrator planning the hardware to run an auction site will also be concerned with the peak loads, which can also be estimated with reasonable accuracy.

The choice of auction rules also affects the load. Consider the effect of the rules used by eBay compared to those used by Amazon's auctions. On eBay, auctions close at a fixed time, regardless of activity. This encourages a bidding technique called *sniping* in which a bidder attempts to place a bid high enough to win at the very end of the auction. In order to execute this strategy, the bidder must have the latest information about the current price, and thus the bidder makes many requests to eBay's server as the auction nears its end. On Amazon, auctions are extended for ten minutes following the last bid, and close when no new bid is received in that period. This avoids the end-of-auction frenzy that is common on eBay and distributes the bidding more evenly over time (Ockenfels and Roth, 2002).

EBay employs two different techniques to help smooth out the load. First, eBay does not give the seller direct control over the closing time of the auction. Instead, the auction closes exactly (to the minute) 3, 5, 7 or 10 days after it is started, where the duration is chosen by the seller. This bounds the number of auctions that can close at a given time by the number that were created at the front end of the time window. Although tools are available that help sellers automate the listing of items, these tools must still operate by interacting (via http or, more recently, XML) with eBay's web servers, and thus are funneled through the gateway. The net effect of eBay's rigid control of auction creation and duration is that auction closings are distributed over time, diminishing the peak loads.

The second approach eBay uses to smooth the load is to allow *proxy bidding*. EBay's proxy bidding system allows users to submit a maximum willingness to pay, and then automatically increases the user's bid on her behalf until the maximum is reached or the auction closes. When users take advantage of eBay's proxy bidding, they reduce the direct interaction with the system. In addition, when two proxy bids are submitted, eBay can directly compute the result of the subsequent bidding war without actually computing all of the intermediate bids. However, the theory (Roth and Ockenfels, 2002) predicts, and empirical studies (Shah, Joshi, and Wurman, 2002) support, that straightforward proxy bidding is not the only strategy employed by bidders.

Despite the fact that eBay provides a proxy bidding feature, third party bidding software is becoming popular with eBay's users. Companies like eSnipe and Auction Blitz offer sniping services, and there are many "free" programs available for download. These sniping tools are quite simple, but the potential benefits of bidding assistants–*agents*– are tremendous, in both C2C and B2B environments. Although auction sites have discouraged these tools, the potential benefits to bidders are so great that it seems unlikely that bidding agents can be suppressed for long. This has serious implications for online auction managers. An architecture in which agents make requests for Web pages and parse them to extract the relevant information is inefficient for both the agent and the server. As the number of automated bidding agents increases, auction sites are going to feel the need to provide specialized communication channels. It is clear that XML will be the meta-language of choice for constructing formal languages for querying and bidding in auctions. Indeed, most market-based research platforms now support XML based messaging (O'Malley and Kelly, 1998).

While we have yet to see bidding agents explicitly designed for B2B auctions, there is a growing recognition of the value of optimization approaches to generating bids. Decision support systems for generating bids in procurement auctions have been demonstrated by IBM (Goodwin, Akkiraju, and Wu, 2002) and others.

COMPLEMENTARY FEATURES OF AUCTION SYSTEMS

Auction systems rarely exist as stand alone Web sites. Generally, an auction Web site provides complementary features that enhance a user's experience with the site. In fact, many of these features are essential to success of an auction business.

The importance of the features will depend upon the particular type of marketplace. Figure 2 shows how several types of marketplaces differ with respect to the number of bidders and the number of differentiated products available. Large C2C markets like eBay have many users and many products simultaneously auctioned. Commodity and security markets, like NYSE, have many bidders but relatively few and static products. B2B exchanges, like FastParts.com or the automotive markets run by Covisint, have a moderate number of products and screened traders. Procurement auctions typically cover fewer products (e.g. contracts) and have a small set of pre-selected suppliers.

<< Insert Figure 2 here. Space of marketplace structures. >>

Personalization

Bidders need an interface that allows them to create accounts, find product listings, and place bids. All sites require that bidders log in to place bids or initiate auctions. Authentication also allows the server to customize the user's view of the auction site. Typically, the custom view lets a user keep track of her bids, watch auctions of interest, and manage other aspects of her account.

Catalogs and Search

Catalogs and *search* features are two methods that enable bidders to find products, and both are typically provided on sites with large numbers of products. Catalogs are based on a natural, hierarchal organization of the products. Generally, catalogs are constructed by the auction managers, and thus the manager needs tools to construct and manage the catalog over time. The placement of a product listing in a catalog is usually left to the auction initiator. Thus, catalogs are effective only if the initiators place the products in appropriate locations.   In C2C auctions, inevitably, some sellers either misunderstand the hierarchy or abuse the freedom, and list auctions in the wrong location. However, enough sellers correctly position auctions in the catalog that it is a very effective way to locate categories of products.

Catalogs suffer from two other problems: they don't work for users who have different hierarchal view of the product space than the catalog organizer, and they often require many "clicks" to navigate. Search interfaces alleviate these problems.   At a minimum, the search interface must provide a case-insensitive search for text in both auction titles and product descriptions. Standard techniques from information retrieval can be used to improve the quality of the results. Better implementations give the user greater control over the search by allowing her to constrain the time, price, or other aspects of the auction. Many search implementations allow the user to scour both open and recently closed auctions. Historical auction data provides valuable information about the recent market prices, and, if past bids are revealed, the bidding behavior of the market participants.

Payment and Escrow

C2C auction sites increasingly offer extra services to improve the security and efficiency of the marketplace. Two of the most common offerings are *payment* and *escrow* services. EBay affiliates with Escrow.com to offer escrow services, and recently purchased PayPal, a popular payment service that had become widely accepted among eBay users. Amazon has integrated payments for auctions into its system-wide 1-Click ordering feature, and guarantees that buyers will be reimbursed, up to specified limits, if they pay and fail to receive the product or the product is materially different than the seller described.[7] To support these efforts, the auction system must be integrated with the payment systems and provide tools to investigate disputes.

Some aspects of electronic payment are more straightforward on B2C and B2B sites, in part because there is less anonymity in these marketplaces, which enables standard payment methods to translate to the electronic domain more successfully. B2C sites generally accept credit cards as a form of payment, while B2B auction sites are more likely to invoke purchase

[7] Information found on Amazon.com's Web site.

orders. However, B2B sites are more likely to be involved in international exchanges, and monetary exchange rates become a factor.

Reputation Management

Reputation mechanisms are another common method of combating the fraud that often comes with the freedom afforded by anonymity. Reputation mechanisms collect feedback about a user and allow her to accumulate a personal history. A positive history is an emblem of trustworthiness that can be used to assure potential trading partners that a transaction will go smoothly. A positive reputation is a valuable asset, and serves to make the site “sticky”; sellers with positive reputations are reluctant to take their business to a new site where they would need to build a new reputation from scratch. Typically, reputation mechanisms collect both a numerical evaluation and text comments. To avoid fraudulent inflation of reputations in a C2C site, users should only be allowed to comment on the users when they have a mutual transaction. In a B2B environment, this type of fraud is less common, and the designers may give the users more freedom to comment on one another.

Although reputation systems have become a *de facto* standard feature, their social effects are not well understood. Negative feedback is exceedingly uncommon (only 0.3% of all transactions were rated negatively (Resnick and Zeckhauser, 2001)), and when a seller does receive negative feedback, he can simply start a new account with a clean reputation. In June 2001, EBay took steps to curtail this behavior by tying seller accounts to credit card numbers. This provides a means to (somewhat) track seller’s identities, though new credit cards are quite easy to get. However, negative reputations remain rare. Resnick and Zeckhauser suggest that there is an atmosphere of reciprocity and retaliation in the feedback system; a buyer is reluctant to submit negative feedback on the seller because the seller will retaliate. Despite these challenges, eBay's reputation system, and others like it, create a sense of community and a perception of trustworthiness, and are considered crucial to the success of a C2C marketplace.

Censorship

The global reach, relative openness, and anonymity afforded by C2C auctions permits the posting of politically incorrect material (i.e., Nazi memorabilia, which is illegal to trade in some countries) or illegal products (i.e., illicit drugs or terrorist weapons). C2C sites have established policies and procedures to filter the postings to eliminated unwanted auctions. In addition, many specialty markets focus on collectable products that are targeted at children. Auction sites that expect to have children visitors must censor the product listings, feedback, newsgroups, and other content submitted to the site to be sure it is appropriate for minors, or create a gateway to prevent minors from accessing the adult-oriented content.

Fraud

Fraud, unfortunately, is common on C2C sites. In fact, the Internet Fraud Complaint Center (IFCC) reports that auction fraud accounts for 64% of all complaints, making it the single most common type of fraud on the Internet (IFCC Report, 2001). The most common type of auction fraud is non-delivery; the buyer sends the money and the seller never sends the product. Many other problems exist as well, including *shill bidding, multiple bidding, feedback extortion*, and false reports of fraud (Freedman, 2000). Shill bids are bids placed by the seller or a collaborator in order to force legitimate buyers to pay more. On eBay, shills appear to be used to ferret out the maximum bid, information that wouldn't necessarily be revealed by the proxy bidding system. Shill detection software would be a complementary feature to in auction software targeted at C2C sites. EBay has a large fraud division, but does not publicize its techniques, and fraud detection is only recently being addressed in the academic literature (Shah, Joshi, and Wurman, 2002).

Multiple bidding is a problem similar to shill bidding, except that it is perpetrated by a buyer to defraud a seller. The buyer uses one identity to bid just enough to win, and a second identity to bid very high. This high bid drives away competition, and eventually wins the auction. Then, however, the buyer defaults on the high bid, and the seller may exercise her option to offer the product to the second highest bidder at that bidder's (significantly lower) price. The seller may report the delinquent high bidder, but may never know that the two identities can be traced to a single individual.

Feedback extortion occurs when a buyer demands a better deal after the auction under the threat of slamming the seller with negative feedback. Negative feedback can be so damaging to a seller's reputation that the seller will often capitulate to the blackmailer's demands. EBay is loath to get too involved in the resolution of these disputes because it opens the door for false reports of fraud for the sole purpose of discrediting competitors.

In B2B settings, the auction initiator will often specify the certified bidders and may actually create accounts on behalf of the bidders. This greatly reduces the opportunities for fraud. In B2B scenarios, bidders may be granted special privileges, as when they are preferred suppliers in a procurement situation. The initiator may maintain more control over the auction, and may have power to intercede if unforeseen circumstances occur, much the way the stock market will suspend trading on a stock with excessive volatility. However, collusion among sellers is still possible, and extremely hard to detect.

Integration

It is common, especially in B2B or B2C settings, for the auction system to be connected to a variety of other software systems. Consider a company selling its products via an auction. When an auction closes, the company needs to update its inventory, compose a shipping request that is routed to the fulfillment department, transfer information about the sale to a CRM (customer relationship management) system, and initiate a billing process. Although XML provides a framework for structured communication between components, integrating these systems still requires a significant amount of time and effort. Thus, administrators of a B2B or B2C site need access to the underlying software components, including the auction engine, the database, the Web server, and the e-mail server, so that they can integrate them with payment systems and other back-end applications that may support billing, inventory management, credit authorization, and logistics.

Often, the auction system will be a component of a larger Web presence, and as such must be integrated into the entire Web site and "branded", raising issues of content management. For example, consider Amazon's auction offering. All of the auction pages share Amazon's common graphic and navigation elements (often referred to as "assets"), which are probably managed by a content management system. Thus, when integrating an auction engine into the larger site, a significant amount of work may go into marrying Web content generated by the auction engine with assets served up by the content management system. The customization tools provided with commercial auction systems vary from simply allowing custom graphics to providing scripting tools to create an entirely custom interface.

In addition to working out the details of data flow between the components being integrated, the developers must consider the effect of the integration on the system's responsiveness. In general, the system is only as fast as its slowest component. Thus, if the auction data is stored in a database shared by other mission critical operations, the combined load may overwhelm the database server. Similarly, if authenticating a bidder involves a query through a bottleneck unified authentication system, users may be unable to get through the front door of the auction site.

The integration issues on a C2C auction site are somewhat different. Although the inventory is managed by third party sellers, the sellers are becoming more technically sophisticated. In fact, many eBay sellers run quite sophisticated operations, and established businesses, both large and small, are using eBay as a direct sales channel. These types of sellers need the ability to connect the outcomes of the auction to their internal order fulfillment processes. Currently, the glue that holds the channel together is provided by small companies that specialize in managing the "auction" distribution channel.[8]

In both C2C and B2B environments, auction managers will need tools to handle the unexpected operational missteps that are bound to occur. For example, most auction sites have a

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[8]The list of companies that provide this service includes Andale, AuctionHelper, Auctionworks, ChannelAdvisor, CommerceFlow, FairMarket, Zoovy, all of which can be found at their respective .com addresses.

policy to extend the duration of auctions that are adversely affected by system downtime. Great care must be taken when the system is brought back online. A naïve implementation of the system architecture will come back on line and notice that a large number of auctions are past due, and will immediately clear them, informing the buyers and sellers of the trades. If the system administrators intend to extend the affected auctions, they would be forced to manually correct the auction and bid data, and inform all of the affected buyers and sellers that the transactions have been nullified. In short, a naïve implementation will create an embarrassing mess. A better implementation will give the system administrators control over how auctions are handled when the system is brought back online, including allowing affected auctions to be extended without clearing, and notifying the auction initiators, and perhaps the bidders, of the changed schedule.

CONCLUSION

All auctions share the same core functionality: admit bids, generate information, and clear. The sequence and frequency with which the auction performs these three actions is specified by the auction rules. The rules also determine what types of bids are acceptable, what format the intermediate information takes, and how trade prices are computed. A configurable auction server will be able to implement a greater variety of auction types by mixing and matching the auction rules. However, this flexibility demands more complex software architecture.

In addition, auction systems vary widely in their ability to integrate with (or provide) a variety of complementary features that are common on Internet auctions. Whether selecting from existing auction engines or building one from scratch, the fit between the software's functionality and the needs of all three classes of users (bidders, auction initiators, and administrators) must be considered. The importance of different features will depend upon the particular type of auction site being developed–a public C2C market has different requirements than a one-time procurement auction with certified participants.

Although there have been dramatic successes and failures in the short history of Internet auctions, they will continue to be a central fixture in the automation of commerce activities. The potential gains from the pervasion of dynamic pricing in the economy far outweigh the short-term costs associated with developing the technologies.

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