INTRODUCTION

Electronic Commerce, a Booming Industry

There is now a gradual shift of many of the traditional business models from the real world to the Internet platform; of these models, auction service is most successful. The existence and development of numerous auction Web sites, such as eBay and OnSale Inc., have demonstrated the survivability of electronic auctions in online transactions.

However, current Web-based systems suffer from shortcomings in the following aspects:

- **Fairness and Friendliness**: Due to the different conditions of Internet connections, users across different regions may suffer from the inadequacy of limited bandwidth, especially when participating bidders are distributed across the world. This global nature also makes online auctions difficult to adapt to the potential users across the world.
- **Security and Privacy**: Security concern is one of the important issues users consider when using electronic transactions. Many users also wish to be guaranteed of privacy when doing business.
- **Intelligence and Flexibility**: The vast majority of electronic auction customers are not Internet experts but ordinary people that do not know much about the technical details. Current Web-based auction systems require too much user intervention. It would be commercially profitable if intelligent assistance is provided.

Software Agents, a Paradigm for Mobile Computing

Mobile agents refer to self-contained and identifiable computer programs that can move within the network and act on behalf of the user (Pham & Karmouch, 1998). The mobile agent paradigm as reported in the literature has two general goals: reduction of network traffic and asynchronous interaction. The mobile agent paradigm proposes to treat the network as multiple agent-friendly environments and the agents as programmatic entities that move from location to location, performing tasks for users.

Research on agent-based e-commerce is still underway (Franklin & Reiter, 1996; Guan, Ngoo, & Zhu, 2002; Guan & Yang, 2004; Guan & Zhu, 2002; Maes, Gutman, & Moukas, 1999; Poh & Guan, 2000; Subramanian, 1998; Yi, Wang, Lam, Okamoto, & Hsu, 1998). Mobile agents have demonstrated tremendous potential in conducting transactional tasks in e-commerce. The architecture proposed here is based on mobile agents. The advantages of mobility, intelligence, and autonomy of the agents are taken, which are actually representatives of their respective owners to perform the auction process. By using this framework, we wish to get rid of the previously listed disadvantages in the current online auctions. Specifically, the features of the system will be as follows:

- **Fairness**: The deficiency of bandwidth and network traffic will be overcome by taking the advantages of the mobility of software agents.
- **Autonomy**: Based on the preferences of an owner, agents can be fully automated to participate in the auction with little or no intervention from the owner.
- **Security and Privacy**: Third-party involvement is introduced to enhance the security and privacy throughout the auction. Agents are protected from malicious attacks during transportation and bidding. Furthermore, with the assistance of the coordinator and the encryption mechanism, the real identity of each participating bidder is protected.
- **Flexibility**: The architecture proposed will serve as a unified framework for various auction types as long as the bidding strategies and competing rules are well defined.

Related Work

There has been much research in agent-based auction systems. The Michigan Internet AuctionBot (http://ecommerce.media.mit.edu) sees itself as an information service that collects the bids, determines the resulting price, and notifies the participating parties about the outcome. The Fishmarket Project (http://www.iiia.csic.es/Projects/fishmarket) evaluates a very narrow field of electronic commerce. Its main focus lies in rebuilding a com-
A complete auction service involves the following aspects: information shopping, auction process, payment, and shipping. In our architecture (Figure 1) however, we are only interested in the auction process and assume that auction-related information has been collected by the participants ahead of time.

Overview

In an English auction, the buyers gather together to bid for a certain product, according to the published rules and preferred strategies. In the proposed architecture, the following are typical:

- **Participants**: The auctioneer agent represents the seller of the products; the bidder agents represent potential buyers who wish to compete for the auction item; the coordinator agent is the coordinator of the auction, the receptionist agent collaborates with the coordinator and serves as the receptionist during the auction. The functions and particulars of each agent are listed in Table 1.

- **Place**: The auction Web host is a secure auction environment provided by a certified third party, widely trusted by the participants.

Admission

Admission is the preparation, namely the reception of agents and the build up of the auction relationship. The admission process will be further divided into two periods: SAFER transport and auction registration. SAFER (Guan & Yang, 1999; Yang & Guan, 2000; Zhu, Guan, Yang, & Ko, 2000), has been proposed as a framework for intelligent mobile agent mediated e-commerce. Our system adopts one of the three proposed transport protocols, the supervised agent transport protocol for the secure roaming of agents to prevent agents from malicious attacks during their transportation. The agent is built up with the bidding strategies customized by the owner and carries the owner’s certificate for identification purpose and his or her public/private key for encryption and signing purpose. Figure 2 illustrates the supervised agent transport protocol.

After the agents have successfully roamed to the destination, all agents are welcome by the auction receptionist. The agents then communicate with the receptionist.
Mobile Agent-Based Auction Services

Figure 2. Supervised agent transport protocol in SAFE

Figures give a sample of the communication between agents and receptionist during registration.

The receptionist and each participating agent will check the qualifications of the others. The receptionist then requests the public key and other necessary information from a bidder for later use and will return necessary information including a unique alias to the bidder. This assigned alias will be used throughout the auction process. The bidder’s real identity is kept in the receptionist’s database and will not be disclosed to other participating agents including the auctioneer. When the deadline for the published admission period is due, the receptionist forwards the registration information to the coordinator, which will be used as the basis for building up an architecture regarding the competitive relationships among various agents.

Figure 3. Communication between agents and the receptionist

Bidding

Each bidding agent is equipped with the owner-customized bidding strategies as instructions for submitting bids. The bidding period is divided into several rounds. There will be a set of predefined secure communication protocols for bidding. Let us give the following definitions before we move on to discuss the details:

- \( A, B, C, W \) denotes the auctioneer, bidder, coordinator and the final winner, respectively.
- \( \langle m \rangle^A \) denotes the encryption of a message \( m \) with \( A \)’s public key \( K \).
- \( S_A(m) \) denote the digital signature of a message \( m \) by a process \( A \), (i.e., with \( A \)’s private key).

Submitting a Bid

When a bidder decides to submit a bid in a round, the following procedures are used:

Step 1.

\[
S_B(\text{alias}+\text{bid})^A
\]

\( B \) prepares a message \( m \) containing its own alias and the bid, which is encrypted with the auctioneer’s public key. \( B \) signs the message with its own private key and sends it to coordinator \( C \).
**Mobile Agent-Based Auction Services**

Step 2.

\[ S_C(<\text{number}<\text{bid}>)^AK \]

Upon receiving the message from \( B \), \( C \) first checks the validity of the message, generates a number (to represent the message thread in the database), and removes the alias from the message and further signs it with its own private key and sends the message to \( A \).

Step 3.

\( A \) receives the message from \( C \) and first checks its validity with \( C \)'s public key. \( A \) then decrypts the original message with its own private key and gets the bid.

**Broadcasting a Bid**

The following procedure is used to broadcast the bid winner.

Step 1.

\[ S_A(<m>)^AK \]

\( A \) prepares the message containing the information for the winner of a particular round, which is signed with \( A \)'s private key, and sends the message to \( C \).

Step 2.

\[ S_C(m) \]

Upon receiving the message from \( A \), \( C \) first checks its validity, decrypts the message and searches the information of the message in his database according to the number provided to find out the matching one to reconstruct the message, which is further signed with \( C \)'s own private key.

Step 3.

Bidders first check the validity of the message and then use \( C \)'s public key to get the information as the result of the previous round.

The coordinator together with the encryption mechanism used is instrumental in achieving the following goals:

First, the auctioneer is kept blind from the bidding process, in that the auctioneer can verify the validity of each bid, but is not able to know who has actually submitted bids. This also helps to prevent the auctioneer from linking the winner with a specific bid. This procedure ensures that the customers can bid anonymously and will not suffer from the release of their bidding information. Secondly, all the bidders are notified of the highest successful winning bid in each round, together with the alias of the originator.

Let us further consider two exceptional cases that might occur during this stage: early withdrawal and late arrival. Before an early withdrawal agent leaves, he needs to consult with the receptionist with his withdrawal and obtains permission from him so that the receptionist may forward the most updated bidding status to the coordinator. In the case of late arrivals, despite the requirement that agent must follow the standard procedure before entering the auction, it may also need to consult with the receptionist about the latest bidding situations.

**Conclusion**

The final stage of the auction is conclusion, in which the auctioneer announces the result of the auction and the final winner and the auctioneer identify each other to ensure nonrepudiation with the assistance of the coordinator. Based on the published rules for the auction, the auctioneer is to decide upon the closing time of the auction and select the final winner from a pool of candidates. The following procedure is used for the successful identification of the winner and the auctioneer.

Step 1.

The auctioneer first sends a message to the coordinator to announce the close of the auction. Upon receiving the acknowledgement from the coordinator, he or she sends the result, which contains the number of the final winning message and the winning bid to the coordinator for verification:

\[ S_A(\text{number}+<m>)^AK \]

Upon receiving the message, \( C \) first checks the validity of the message, then retrieves the information from his database according to the number provided to find the alias of the person who submits the winning bid. The coordinator then formally announces the result of the auction.
Mobile Agent-Based Auction Services

Step 3.

The coordinator sends the signed message which contains the information and real identity of the auctioneer and the winner to each party encrypted with their own public keys respectively. The coordinator also needs to send the final result to the other participating agents. However, the message \( m' \) he or she sends to the losing bidders contains only an alias of the winner. Upon receiving the message, the winner and the auctioneer will first verify its authenticity and then save the information regarding identities.

Step 4.

The winner and the auctioneer exchange the identification token, which possibly includes for each party’s real identity and other information, such as the agreement on the delivery of goods.

Implementation

A simple prototype has been developed and implemented to prove the feasibility of agent-based auction systems. It is deployed to ensure that security, privacy, user anonymity, and fairness are attainable in agent-based e-auctions. The overview of the architecture is shown in Figure 4.

Descriptions of the Prototype

The three main components realized in this prototype are as follows:

1. The user interface consisting of the agent factory panel and the auction host panel;
2. The agent factory, where a bidding agent is fabricated according to the user’s needs; and
3. The auction host system, whereby the auction is conducted.

Figure 5 depicts the scenario of the components implemented.

In this prototype, a user customizes an agent by setting parameters such as user identification number, maximum and minimum bids, user IP address, port number, and the desired product he or she wants to buy. When the user clicks the submit button, a Java agent is automatically generated according to these parameters. The agent is sent to the user’s machine.

Running on the auction host is a multithreaded server “coordinator” that talks to the bidding agents and the auctioneer agent in a synchronized manner, as is shown in Figure 6. Once the bidding agent is invoked, it begins to establish a socket connection to its home host. The auction host will spawn child processes or threads to handle communication between bidders and auctioneer in a synchronized mode.

Implementation Issues

There are two possible ways of customizing agents:

- **Local Agents & Local Customization (LALC):** Agents are software programs downloaded and possessed by owners. Agents can be customized by the owner with his preference in bidding strategies and other specifications. The owner sends out the agent to the remote host for an auction and the
Mobile Agent-Based Auction Services

agent returns to the owner when the task is completed. The owner can still maintain communication with his bidding agent.

• Remote Agents & Local Customization (RALC):
Agents are standalone programs which reside in the auction hosts. Users may use the browser to select the proper agent and customize it with his or her bidding strategies and other preferences by way of standard CGI forms. The user-customized agents will then be sent and automatically invoked to start the auction at the remote host. We have adopted the latter scheme in our implementation.

IMPACT OF MOBILE AGENT–BASED AUCTION SYSTEMS

The intelligence and autonomy of mobile software agents will enhance the performance of agents in auctions and reduce the workload for users. Our proposed agent-based system provides a flexible and unified structure for various types of auctions, in which both security and user anonymity are guaranteed. The proposed system is suitable when users want to be relieved from auction details or when the auction value is small. It will be useful when it is used with wireless devices, such as handphones, where users generally stay off-line and are interested in the results only.

CONCLUSION

In the previous sections, we have discussed in details the architecture for an agent-based electronic auction system. Compared to existing Web-based auctions, our proposed scheme exhibits some unique features and advantages when addressing the issues of security, privacy, fairness, and flexibility.

One of the attractive features of using software agents in an auction is its autonomy and intelligence. Given such a system, a good bidding strategy becomes the critical factor to win. A good strategy should be adaptive enough so as to respond rapidly and intelligently to the behaviors of the other partners. Agents equipped with such strategies will be “smart” while at the same time remain vigilant and faithful to their owners.

The proposed agent-based auction system may also provide an interface for future implementation with communication to devices such as wireless application protocol (WAP) phones. The proposed agent-based scheme also brings in new commercial opportunities for the Internet service providers, such as providing the programs for software agents, the design and implementation of intelligent bidding strategies, and so forth. The system will also inspire novel types of auction services that have no counterpart in the real world, enriching business content in the Internet world.

REFERENCES

AmEC Initiative at Massachusetts Institute of Technology. Retrieved from http://ecommerce.media.mit.edu/

Mobile Agent-Based Auction Services


**KEY TERMS**

**Adaptability:** The ease with which software satisfies differing system constraints and user needs.

**Agents:** A piece of software, which acts to accomplish tasks on behalf of its user.

**Anonymity:** The degree to which a software system or component allows for or supports anonymous transactions.

**Cryptography:** The art of protecting information by transforming it (encrypting it) into an unreadable format, called “cipher text.” Only those who possess a secret key can decipher (or decrypt) the message into plain text.

**Flexibility:** The ease with which a system or component can be modified for use in applications or environments, other than those for which it was specifically designed.