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## **BUILDING A SEMANTIC TENDERING SYSTEM**

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### **ABSTRACT**

In the new B2B e-commerce arena, applications such as auctions and data exchange are growing rapidly. However, Web content is currently designed for human consumption rather than computer manipulation. This limits the possibility of Web automation. Fortunately, the new development of the Semantic Web that allows Web pages to provide information not only in terms of their content, but also in terms of the properties of that content, can be used for automation. Electronic tendering systems are among the successfully commercial systems that can tremendously benefit from the availability of Semantic Web. This study proposes an e-tendering system that uses the Semantic Web to investigate the automatic negotiation process. The system is built in a P2P environment to simulate a two-player negotiation. It is found that the ontology of semantic information can be used to locate qualified suppliers and precede negotiation. The bargaining power of each party is then determined by the relative magnitude of the negotiators' respective costs of haggling and the utility that varies with the degree of risk preference. Our experiments showed that applying automatic negotiation strategies to e-tendering system in semantic web can reflect the risk preference of the participants.

*Keywords:* Semantic Web, negotiation, P2P, e-tendering

### **INTRODUCTION**

In the past decade, the boom in Internet technology enabled a platform for the accumulation and sharing of vast ranges of information among people, organizations, and enterprises. However, most of the information is written in HyperText Markup Language (HTML), which mainly follows a rigid format for displaying the content. This information is normally written for human comprehension. As information volume has been vastly growing, the time that is needed to locate and digest the information also increases tremendously.

In contrast to syntax-based HTML, the Semantic Web [1] organizes Web content into information (*facts*) and the meaning of that information. According to the American Heritage Dictionary of the English Language (Third Edition, 1996, Houghton Mifflin Company), semantics is the study or science of meaning in language forms, or a study of relationships between signs and symbols and what they represent. The Semantic Web, as does the World Wide Web, encourages the independent and diversified growth of Web sites while maintaining a high degree of information sharing among them. In the Semantic Web, a Web page provides information not only in terms of its content, but also in terms of the properties, called *attributes*, of that content. In this way, the use of information, such as when searching, is not limited to exploring its content, but can be extended to its properties. For example, conventional searches require a user to type in keywords, for which the search engine searches over the Internet (or through downloaded files). In the process, the volume of search results can be tremendous and some of the material is not very well related to the keywords. However, when the search is applied to a Web page that has been written in a Semantic Web language, such as eXtensible Markup Language (XML) or the Resource Description Framework (RDF), the search can be extended to the properties of the Webpage and the results are likely to be more concise and relevant. This has enhanced the possibility of having a highly automated and integrated Web service [2].

Recently, the electronic marketplace has allowed the emergence of many different types of dynamic pricing schemes. The electronic auctions of eBay and Dell and the reverse auctions of GE and GM are all successful cases. These systems are built to provide for bargaining between one buyer and one seller, forward auctions for multi-buyers and one seller, reverse auctions for one buyer and multi-sellers, and dynamic exchanges for multi-buyers and multi-sellers. The need for an automated, efficient, and trustworthy system has grown correspondingly.

In this study we developed an e-tendering system on a P2P Semantic Web and simulated the negotiation process of the e-tendering service, i.e., a reverse auction. Note that the peer to peer (P2P) architecture offers a decentralized and distributed network to avoid co-ordination bottlenecks [3]. A pure P2P sharing network is basically an information directory in which explicit knowledge is maintained on local computers [4]. In the e-tendering system, the P2P environment is engaged to simulate a two-party negotiation. The e-tendering system allows the negotiation to be done in a one-to-one manner and the seller who gives the best offer is selected to win the tender. A utility function (representing the anticipated payoff for each party corresponding to its selected strategies) is employed to determine the settlement. The bargaining power considering the relative magnitude of the

negotiators' respective costs of haggling and risk preference is applied to find the settlement. The utility function of negotiators and their bargaining power are modeled in the semantics of Web pages. A case study is presented for the purchasing problems that arise when there is one buyer, 10 sellers, and multi-bargaining issues.

### SEMANTIC WEB SERVICES

The semantic Web is similar to a deductive database and a knowledge-based system, where new knowledge is deduced by applying rules to existing facts. The difference between these systems is that both the knowledge-based system and the deductive database apply rigid structures to the knowledge representation and deduction rules to ensure that new knowledge can be obtained by inference; in contrast, the Semantic Web allows Web sites to represent knowledge and rules in their own ways. In the Semantic Web, both facts and rules (called *ontologies*) bring meaningful content to Web pages [1]. The Web site information is then shared using software agents. A brokering service can be used to help software agent to discover relevant services [5]. If the ontologies of the service are not familiar to the service requester, then translation between different agents is needed [6].

Most current studies of the Semantic Web focus mainly on the knowledge representation and services carried out by the software agents of individual Web sites, such as ontology design, the visual environment for browsing, RDF model and syntax specification, and Web services with ontologies (<http://www.w3.org/>). Since the W3 Consortium advocated the concept in 1999, several applications have been successfully implemented. For example, card index information, privacy information (P3P), the associations of style sheets with documents, and intellectual property rights labeling can be found at (<http://www.w3.org/DesignIssues/Semantic.html>, accessed on September 2005). An algorithm to extract ontologies from the structured data of electronic data interchange for tendering domain is provided in [7]. An electronic government procurement system with the functions of posting and receiving bids via the Internet, vender registration, certificate authorization, contract development tools, bid/request for proposal (RFP) development, online bidding, and online payment to render government procurement efficient, transparent, nondiscriminatory, and accountable is given in [8]. Semantic process templates that use ontologies to capture much richer descriptions of activity requirements and a more effective way of providing Web services is described in [9]. Finally, conceptual architectures of both Semantic Web services and Web services to enable Semantic Web Service design and composition at the knowledge level in a language-independent manner is provided in [10].

### MODEL

This study applies P2P architecture, simulated as a decentralized two-party bargaining process, in a semantic Web to the negotiation process for an e-tendering system. We assume that the two parties have a common interest in cooperating, but also have conflicting interests over exactly how to cooperate [11]. There are many definitions of negotiation. Oliver [12] considered negotiation as simply a searching process in a multidimensional problem, when each solution is considered as a dimension. Krovi et al. [13] defined negotiation as a way to resolve issues between two or more parties with opposite positions. Nunes et al. [14] assumed that negotiation is a decision-making process for reaching a consensus between collaborative parties rather than opponents. This study considers negotiation as a multiple-criteria decision-making (MCDM) problem, i.e., a multi-*attribute* decision making problem, where many criteria are taken into account as attributes for decision-making [15].

In the past decade, many investigations have resulted in negotiation systems. In general, they can be categorized into automated negotiation systems (ANSs) and negotiation support systems (NSSs), where ANSs emphasize on building of automatic negotiation processes and NSSs provide more information and strategies to the negotiators. ANSs mainly employ intelligent agents or mobile agents to travel between computers to simplify the negotiation process with machine learning techniques, such as genetic algorithms [12], rule-driven reasoning [16], game theory [15], fuzzy logic [17], and ebXML [18]. Unlike ANSs, NSSs mainly suggest solutions or provide process support. The adoptions use social-judgment theory models, genetic algorithms [19], hyper-game decision models, bargaining models, and multi-objective linear programming [20]. Similarly, Kromker et. al. developed software to support the distributed processes in a heterogeneous system environment for preparing tendering bids which require interdisciplinary co-operation [21]. However, current research investigations on the building of negotiation systems focus on either system development or machine intelligence, rather than on the negotiation process itself. Thus, our focus on the negotiation process is the major distinction with other related work in the literature.

#### *Semantics in P2P negotiation*

The semantics of P2P negotiation are expected to appear in three areas where incomplete information can be found. Here, incomplete information means that one party has some knowledge in common with its opponent, but also has private knowledge that is unknown to the other party. The criteria for a negotiation are described as follows:

(1) Partner selection: the semantic information can be used to select partners or services dynamically [9]. The partners are selected from a community, whereby the initiating entity (buyer *b*) locates a partner (seller *s*) based on preset criteria. The ontology can be referred to for selecting suppliers. Generally speaking, two types of relationships are presented in the ontology: "is-a-kind-of" and "is-a-part-of". These relationships assist in the selection process to locate more suppliers who can provide products that are close to the item that the buyer is looking for. For example, a company that sells desktop PCs, tablet-PCs,

handheld PCs, notebooks, and others may be the candidate seller when a buyer is looking for tenders for a PC with a particular specification.

A negotiation is performed in a one-to-one manner between a buyer and a seller, but many negotiations can be activated concurrently. A negotiation issue, such as the price that is offered by one negotiator, is denoted in the ranges of  $[I_i, R_i]$ , where  $i \in \{b, s\}$ ,  $I$  is the initial offer and  $R$  is the reserve price. A buyer locates a seller for further bargaining when  $\sum_j I_{sj} \geq \sum_j R_{bj}$  where  $j =$

$\{0, 1, \dots, n\}$  when multiple issues are adopted such as the delivery time, quantity of items required, inventory levels, and payment methods. Both parties then determine the best alternative to a negotiated agreement (BATNA) referring to the reservation points.

The first offer from a seller to a buyer is  $o_{s \rightarrow b}^t$  where  $t = 1$  after receiving request for quotation (RFQ) from buyer  $b$  and  $t \in T$  and  $T = \{0, 1, \dots, m\}$ . The buyer will accept the offer if she knows that the next offer may not be better than the current offer, i.e.,  $U_b(o_{s \rightarrow b}^t) \geq U_b(o_{s \rightarrow b}^{t+1})$ , where  $U$  is the utility function of  $b$  obtained from the offer of seller  $s$  at time  $t$  compared with time  $t+1$ . Similarly, the seller will accept a counter offer if he/she knows that the next offer may not be better than the current offer, namely,  $U_s(o_{b \rightarrow s}^t) \geq U_s(o_{b \rightarrow s}^{t+1})$ .

(2) The bargaining power of each party is determined by the relative magnitude of the negotiators' respective costs of haggling and the utility that varies with the degree of risk preference. The costs of haggling take into consideration time discounting, deadlines, time constraints (waiting-time costs), or inventory levels, while the risk preference considers the attitude of the negotiator, such as risk-neutralization, risk-aversion, or risk-proneness. A negotiator is considered to be a patient player when the time-discounting rate is small.

In the e-tendering system, each entity that participates in the negotiation should have a negotiation engine. The engines of both parties determine the results based on the bargaining powers of them. Models, such as that of Rubinstein [22], which assume a constant discount rate of future utilities, are modified for this purpose.

(3) Different strategies can also be adopted in negotiation [23]. For example, new issues can be created to transform a single-issue fixed-line negotiation into integrative negotiations. Moreover, an offer can be made for a complete package at one time or for the items issue-by-issue. At this stage, the bargaining issues may also be unbundled. That is, the weights of bargaining issues can be changed. Multiple offers can also be made simultaneously, meaning that at least two proposals of equal values can be made together.

### Utility Function

The utility function represents the anticipated payoff to each party corresponding to their selected strategies (<http://en.wikipedia.org>). How can the utility function of a negotiator (whether an individual or an organization) be obtained from the semantics of web pages is beyond the scope of this study. In this study, the multi-attribute utility theory (MAUT) is adopted to help a decision-maker to quantify and derive solutions with multi-criteria. The total utility can be obtained by summing up

weighted issue utilities, i.e.,  $U = \frac{\sum W_i \times U_i}{\sum W_i}$ , where  $U$  is the total utility value ranged between 0 and 1,  $i$  is the negotiation issue,  $U_i$

is the utility value of an issue ranged between 0 and 1, and  $W_i$  is the weights of issues ranged between 1 and 9. Applying the Neumann-Morgenstern utility function for modeling [24],

$$U_i(o_{i \rightarrow i'}^t) = U_i(o)U_i(t) \quad (1)$$

where  $U_i(o)$  is the utility function of a negotiator  $i$  derived from the offer of the other negotiator  $i'$ ,  $U_i(t)$  is the discount rate  $f(\alpha)^t$  of issue  $i$ , and  $\alpha$  is the discount factor. As we assume a constant discount rate, the discount rate will be determined at the beginning of the negotiation. The negotiator is a patient player when  $\alpha > 1$ . In this study, the discount factor is a factor of the cost of haggling and is determined by the semantic data. The utility function is measured in a linear function:

$$U_j^i(o_{j, i \rightarrow i}^t) = \frac{O_j - R_j}{I_j - R_j} \quad (2)$$

for seller to issue  $j$ , and

$$U_j^i(o_{j, i \rightarrow i}^t) = \frac{R_j - O_j}{R_j - I_j} \quad (3)$$

for the buyer to issue  $j$ .

The interaction of the utility functions of both parties may form a bargaining zone. A positive bargaining zone implies that there is room for both parties to reach an agreement. In general, agreements are categorized into three levels. At the first level the

agreement is located in a positive bargaining zone and is better than the reservation points of both parties. At the second level the agreement is better than the expectations of both parties. The second level is possible because this is not a fixed-sum multi-issue negotiation, and it is possible to reach an agreement that can simultaneously improve the outcomes of both parties. The third level is called the *Pareto-optimal frontier*. At this level it is impossible to improve the agreement without sacrificing the benefits of any party.

### Counter-Offer

The counter offer consists of tactics that vary the acceptance value of an issue depending on the remaining negotiation time [24].

$$o_{i \rightarrow i'}^t(j) = \begin{cases} I_j^i + \mu_j^i(t)(R_j^i - I_j^i) & \text{if } i = b \\ I_j^i + (1 - \mu_j^i(t))(R_j^i - I_j^i) & \text{if } i = s \end{cases} \quad (4)$$

Function  $\mu_j^i(t)$  is called the *negotiation decision function* to issue  $j$  for negotiator  $i$  and is defined as

$$\mu_j^i(t) = k_j^i - (1 - k_j^i) \left(\frac{t}{T^i}\right)^{1/\varphi} \quad (5)$$

The negotiation decision function should be between 0 and 1 (i.e.,  $0 \leq \mu_j^i(t) \leq 1$ ) to ensure that a settlement can be reached. At time 0,  $\mu_j^i(0) = k_j^i$  is a constant value to determine the initial counter proposal. When  $t = T$ , the maximum time is  $\mu_j^i(T) = 1$  and the counter offer will be the reservation value since the deadline has been reached.

Risk preference can be reflected through the negotiation decision function, in which a *risk-aversion* attitude adopts conceder behavior, a *risk-proneness* attitude takes Boulware behavior, and a risk-neutralization shows no preference. The Boulware tactic [25] has  $\varphi < 1$  while conceder tactics [26] has  $\varphi > 1$ . In Boulware behavior, the negotiator maintains an offer close to the initial offer until the time nears the deadline. In contrast, the conceder behavior gives way to the reservation value quickly.

Equation 5 considers haggling cost as the constraint. In fact, many other resources should also be taken into consideration, such as the current inventory level and consumption rate. Therefore, equation 5 is further revised into

$$\mu_j^i(t) = k_j^i - (1 - k_j^i)(X)^{1/\varphi}, \quad (6)$$

where  $X$  is the combination of all resources. It should be noted here that the number of resources to be considered is decided by the negotiation engine in the P2P Semantic Web.

## SYSTEM DEVELOPMENT

A system was developed to simulate the auto negotiation in an e-tendering system with P2P architecture using JXTA, developed by Sun Microsystems. Note that JXTA™ technology is a set of P2P open protocols that can connect various devices to a network ranging from cell phones and wireless PDAs to PC servers. JXTA peers create a virtual network where a node can interact with other peers or resources directly, even when they are behind a firewall or have different network transports.

In a P2P environment, each node on the network is known as a peer. They can communicate with each other through sending messages. In a traditional e-tendering system, there is usually a central server to receive and route queries and response messages (such as an RFQ, an acknowledgment, or a counter offer). However, in a B2B (business-to-business) environment, it is reasonable to assume that the peers are behind firewalls and NATs (Network Address Translations). Therefore, some peers are needed to take care of jobs like routing and translating. These peers, known as relays, include rendezvous peers, router peers and gateway peers. For some large-scale Intranet systems, dedicated peers may be specialized to perform each kind of job.

The class diagram of the e-tendering system is shown in Figure 1. Basically, the system includes nine classes: the buyer, the seller, the product, P2PQueryMsg, P2PResponseMsg, P2PNeg, P2PHandler, CustomerInfo, and ResolverService. Brief descriptions of these are given in Table 1.

**Table 1 Description of E-Tendering Class Diagram.**

| Class  | Method   | Description  |
|--------|--|--|
| Buyer  | <b>double</b> cal_offer (int cur_time, Product prod, double k, double ini_price, double res_price) | Generates offers and counter-offers. It first finds the stock of the materials, and then checks the inventory level and turnover rate of the product that it uses. It computes the deadline of the negotiation based on these figures and finally calculates the offering price. |
| Seller | <b>double</b> cal_offer (int cur_time, Product prod, double k, double ini_price, double res_price) | Generates offers and counter-offers. It computes the deadline of the negotiation based on the data that it has found from semantic web, and then calculates the offering price.  |

|                |  |   |
|----------------|--|---|
| Product        | <b>int</b> getStock()  | Gets the inventory level of the product.  |
| Product        | <b>int</b> getTurnover()   | Finds the turnover rate of the product.   |
| P2PQueryMsg    | P2PQueryMsg (String peer_id, String material_id, int t, String seller_id, double inventory)    | Constructor of a query message, with the attributes and values specified.   |
| P2PQueryMsg    | P2PQueryMsg (InputStream stream)   | Constructor of a query message with an XML document.  |
| P2PQueryMsg    | <b>boolean</b> comUtility(offer_price)   | Compares the utility that the buyer would gain from its proposed price with that of the current price offered by the seller.                    |
| P2PResponseMsg | P2PResponseMsg (String peer_id, String material_id, int t, String seller_id, double inventory) | Constructor of a response message, with the attributes and values specified.  |
| P2PResponseMsg | P2PResponseMsg (InputStream stream)  | Constructor of a response message, with an XML document.  |
| P2PResponseMsg | <b>boolean</b> comUtility (double proposed_price)  | Compares the utility that the seller would gain from its offered price with that of the current price proposed by the buyer .                   |
| P2PNeg         | <b>void</b> manageHandler()  | Registers or de-registers the command.  |
| P2PNeg         | <b>int</b> parseArguments()  | Parses the arguments following the command.   |
| P2PNeg         | <b>int</b> startApp()  | Starts the application by sending out an initial query.   |
| P2PHandler     | <b>int</b> processQuery(P2PQueryMsg qmsg)  | Seller peer processes. The price proposed by the buyer is accepted if it is considered reasonable; otherwise, the seller makes a counter-offer. |
| P2PHandler     | <b>void</b> processResponse (P2PResponseMsg rmsg)  | Buyer peer processes. The price proposed by the buyer is accepted if it is considered reasonable; otherwise, the buyer makes a counter-offer.   |

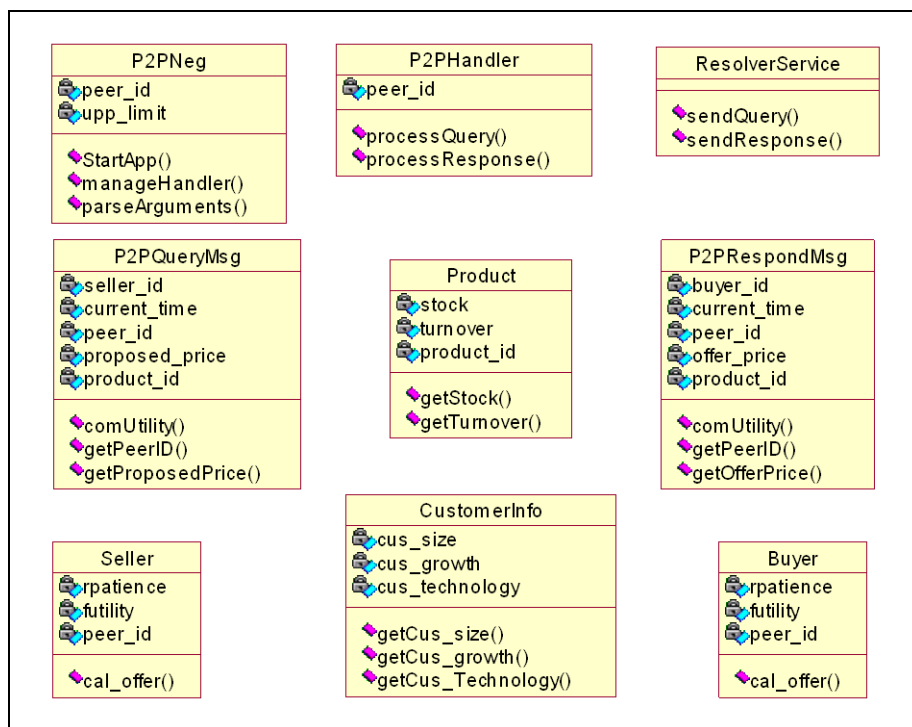
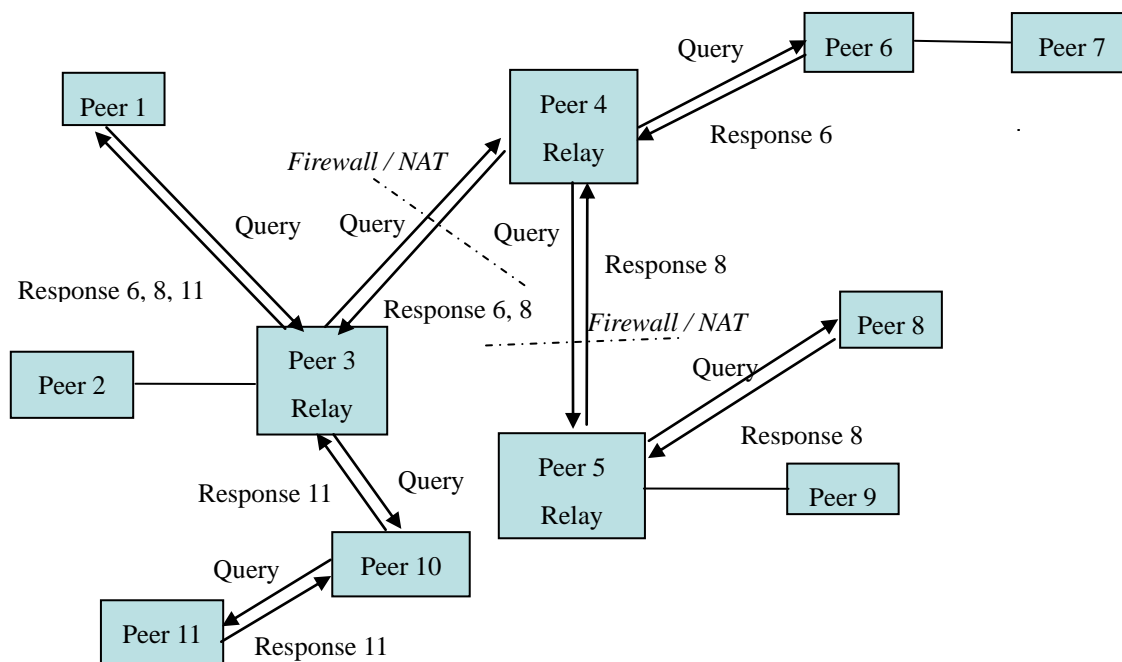


Figure 1. Class Diagram of a P2P E-Tendering System

With the help of JXTA technology, the workflow becomes simple. For example, in Figure 2, Peer 1 searches suppliers for a product in the following steps:

- (1) Peer 1 initiates a search request for suppliers.
- (2) As the partners are outside the company, Peer 1 will not search peers within the same intranet.
- (3) As only relay peers can be searched by outside parties as defined by JXTA, a node searches its relay peer first. In this example, Peer 1 hopes to communicate with peers beyond the firewall, so it sends the query to a relay peer, i.e. Peer 3.
- (4) Peer 3 has cached information about the other relay peers that it should associate with. In this example, it finds relay Peer 4 and Peer 10.
- (5) Peers 4 and 10 search peers belonged to their local network and obtain responses from Peer 6 and Peer 11, respectively.
- (6) A relay peer can forward the query to other relay peers from its cached information in case these relay peers have not yet participated. Here Peer 4 forwards the query to Peer 5 and gets a new reply from Peer 8.
- (7) All of the replies are sent back to Peer 3 and eventually sent back to the initiator, Peer 1.



**Figure 2. An Example of Locating Peers in P2P**

After locating the peers, the negotiation process starts. In the P2P Semantic Web, negotiation strategies are built in each node while the ontologies are maintained in the relay peer. In general, the ontologies are not modified frequently. Updates to the relay peer should be conducted only when all the relay peers have reached consensus. The negotiation process starts when a buyer sends a RQF to a supplier (the sequence diagram is shown in Figure 3). Then, the P2PHandler class built in JXTA is used to process the query message sent to the node. The node applies methods provided by different object classes to extract the information necessary to calculate the offer and sends it back to the buyer, as shown in Figure 4. A counter-offer is made by referring to strategies built in the buyer, as shown in Figure 5. The process is repeated until a settlement that satisfies both parties is reached. Finally, the seller selects the best final offer from all suppliers and makes a deal with the selected supplier.

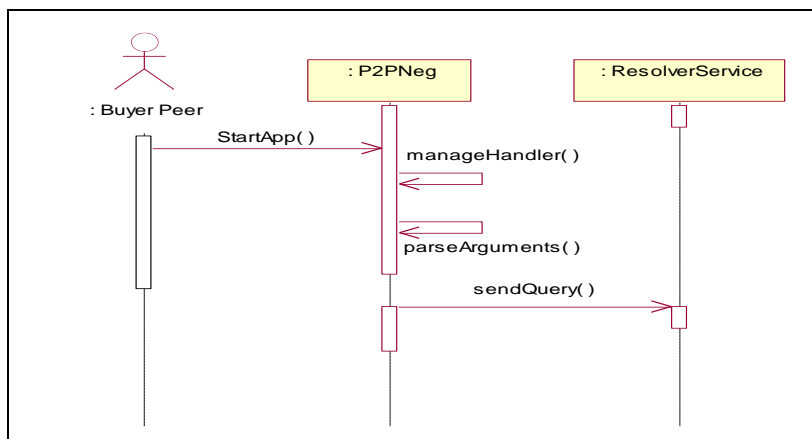


Figure 3. The Sequence Diagram describing the Scenario when a Buyer Sends a RFQ to a Seller

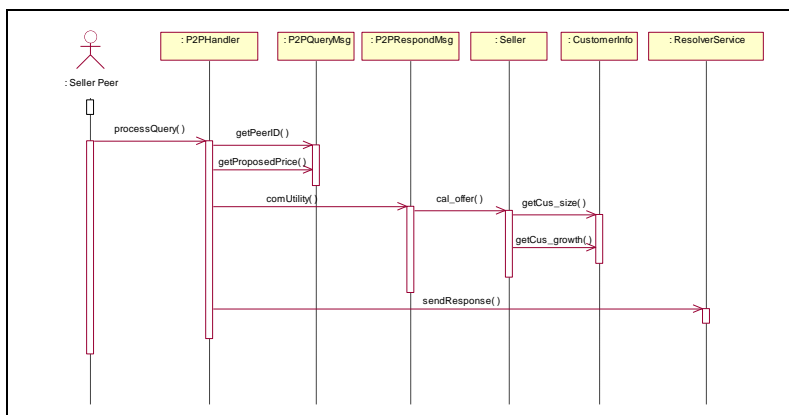


Figure 4. The Sequence Diagram to Generate an Offer from a Seller to a Buyer

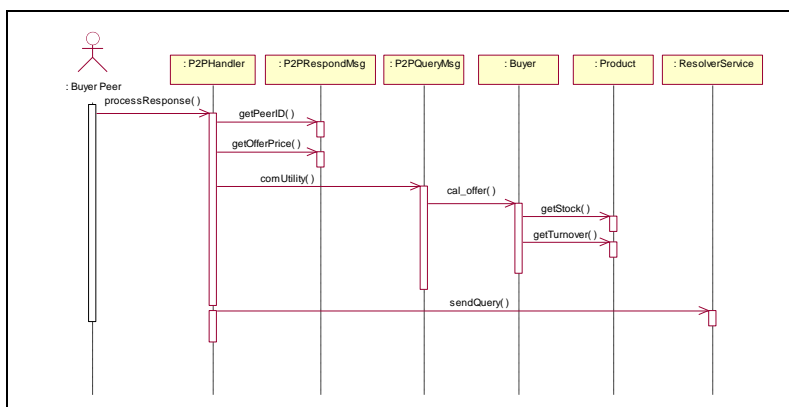


Figure 5. The Sequence Diagram to Generate a Counter-Offer

This approach has the following advantages:

1. No centralized server is needed to group all the queries and responses, because a peer is a client as well as a server under the P2P concept, and it is able to handle all the necessary actions concerning a query.
2. The peers share the burden of jobs. Although it seems that the relay peers are handing extra work, in fact the workload is not heavy, as they have only to send forward queries from their local network and leave the jobs related to outside parties to their own peers. What they have to do is only to forward a message to their known relay peers and ask these relay peers to perform the job. This approach requires only the idle resources of current machines rather than installation of new workstations to perform centralized jobs.
3. Although one relay peer, say Peer 3, stores only a limited amount of cached peers, as the relay peers are able to forward the request further, the multiple effect could be very messy. However, this does not multiply the workload of Peer 3 as the jobs are shared among all the peers.



## CONCLUSION

In the new era of B2B e-commerce adoption, services such as auctions, data exchange, and negotiations have gained greater attention. However, Web content is currently designed for human consumption rather than computer manipulation. The consequence is that a user has to make a tremendous amount of effort to find needed information from millions of search results based on selected keywords. Fortunately, a new approach, the Semantic Web, structures the meaningful content of Web pages into semantic data. This provides the possibility of Web automation. This pioneering study explored the possibility of Web automation in an e-tendering system characterized by the different risk preferences of the negotiators. The architecture is built in a P2P environment to simulate a two-player game although each player can aggregate the needs of many buyers or sellers. In the P2P environment, the negotiation is conducted in a one-to-one manner and the best offer is selected as the tender. It is found that the ontology of semantic information can be engaged to locate suppliers who qualify for the negotiation to commence. The bargaining power of each party is then determined by the relative magnitude of the negotiators' respective costs of haggling and the utility varying with the degree of their risk preferences. In the future, the study could be expanded into one-to-many (auctions), many-to-one (reverse auctions), and many-to-many (exchange) negotiations.

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