Forming Dynamic Supply Chains in the Electronic Marketplace: A Partnership Negotiation Mechanism

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Abstract

Recent researches on agent-mediated electronic commerce focus on automating interactions between buyers and sellers. These automations are fundamentals of supply chain formation, but not enough in facilitating dynamic partnerships which consist of more than two partners. In this paper, we explore business roles within a supply chain from a higher-level viewpoint, and identify their special cooperation requirements. We propose a partnership negotiation mechanism to facilitate their cooperation. An experimental electronic marketplace is implemented to test the negotiation mechanism. The results show that it facilitates formation of dynamic supply chains, which improves efficiency of an electronic marketplace.

Keywords: electronic marketplace, multi-agent system, negotiation protocol, electronic commerce

1 Introduction

Electronic commerce (e-commerce) is the ability to conduct business via electronic networks such as the Internet and the World Wide Web. Emphasis these days is on agent-mediated electronic commerce [19], where e-commerce is automated and coordinated by communicating agents. Many electronic marketplaces, such as eBay [6], OnSale [14] and Kasbah [12], have been created to automate activities in a commerce model. Automated activities include product brokering, merchant brokering, and negotiation. These automations focus on facilitating buyer-seller interactions, which can be categorized using consumer-buying behavior model (CBB model) [5,11]. The ongoing research project Kasbah demonstrates a way of transacting goods via agents negotiating on users' behalves. Research on auction mechanisms [4,15,18,20] serves as the fundamental of these negotiation protocols. Other researches on reputation mechanism [3,21,7] further address issues of trust among parties in marketplaces or communities. Business-to-consumer and consumer-to-consumer electronic transactions have been transformed fundamentally. The next step lies at ways to streamline business-to-business transactions. Research [19] suggests the possibilities of dynamic agent-coordinated business partnerships that exist only as long as necessary.

Research in negotiation protocols of contracting is essential to the formation of business partnership. Smith's Contract Net [17] is a pioneered research in communication among cooperating distributed agents. Sandholm and Lesser [24] extended it to self-interested agents. John Collins, Scott Jamison, et al have explored temporal strategies [9] and market architecture [8] for multi-agent contracting. Nevertheless, all of them focus only on automating customer-supplier interactions. We argue that, from a higher-level viewpoint, roles in a business partnership may have cooperation requirements that cannot be achieved via simple customer-supplier negotiation. Take personal computer (PC) industry as example. There exists a role of integrator (Figure 1), who integrates PC components and sells PCs.

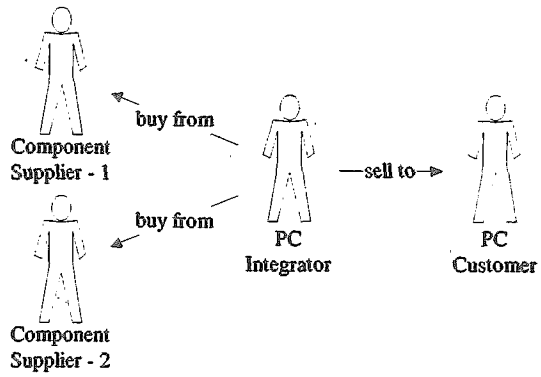

Figure 1. PC Integrator

Although integrators can buy PC components firstly and sell integrated PCs afterwards, most of them would prefer to buy PC components after PC requests from buyers have been confirmed firstly, therefore the risk of purchasing unwanted components and the inventory cost can be reduced [13,16]. We name this requirement a just-in-time purchase. Under just-in-time purchase, integrator no longer buys and sells independently. PC requests from customers trigger purchases of PC components, and the business partnership is formed dynamically to fulfill the requests. Implementation of this requirement is difficult under current negotiation mechanisms, since the buy and sell negotiations are automated independently. If software agents can understand the meaning of being an integrator, they can be extended to negotiate more.

In this paper we focus on facilitating the cooperation of multiple parties playing different roles. The network models of these higher-level business roles and the identified cooperation requirements are discussed in the next section. In section 3, the mechanism to facilitate the cooperation of them is proposed. The experimental electronic marketplace implemented to test the mechanism is presented in section 4. Drawn implications and conclusions are presented in the last section.

2 Business Roles within a Supply Chain

In this section, we explore business roles within a supply chain. The goal of this exploration is to identify high-level cooperation requirements that are not able or are difficult to be achieved under current agent-mediated electronic commerce.

2.1 Business Roles

The industry organization can be viewed as chains of supply. Within these complicated chains, roles can be identified by how they are related with other roles. We define Customers to be those who buy products, and Suppliers to be those who sell products. A generic supply chain example is given in the following:

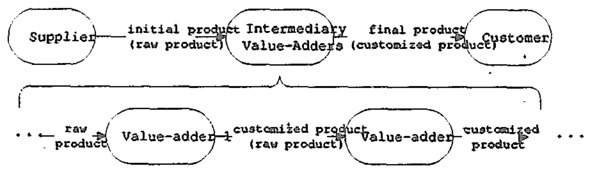

Figure 2. A supply chain example

Roles between suppliers and customers are intermediary value-adders, who create and add value to the initial product. Each value-adder receives raw products and produce customized products. A value-adder is different from simple buyer and seller since he buys and sells simultaneously. In other words, a value-adder earns his living by selling customization services instead of raw products.

We define types of value adders according to their relations with suppliers and customers.

1. *Transformer* (one-to-one): Transformers are value-adders that buy one kind of product from suppliers, and after some transformation, sell another kind of product to consumers. A tuner is a good example of transformer, he transforms untuned equipment into tuned one.
2. *Integrator* (many-to-one): Integrators are value-adders that buy two or more kinds of products, and after some integration process, sell integrated products. PC integrator is a typical one.
3. *Disintegrator* (one-to-many): Contrast to integrators, disintegrators buy only one kind of product, and after some disintegration process, sell components of various kinds. Knackers that disintegrate ships or houses are examples of this kind.
4. *Synthesizer* (many-to-many): We define synthesizers to be value-adders that buy two or more kinds of products, and sell two or more kinds of products after specific synthesizing processes. For example, a chemical factory produce byproducts from the raw products purchased.

Their network models are illustrated in Figure 3.

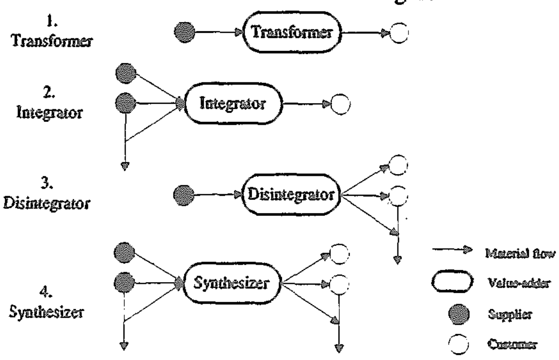

Figure 3. Business roles

2.2 Cooperation Requirements of Value-adders

In order to cooperate with other roles in a supply chain, parties in the market have to negotiate with each other for various terms of the transactions between them. Auction technology [4,15,18,20] has been used to automate the negotiation between buyers and sellers in electronic marketplaces. Nevertheless, value-adders are different from simple buyers and sellers since they buy and sell at the same time. Due to this special characteristic, we are able to identify two extended cooperation requirements that help value-adders response fast to the demands and resources available, and do their business "just-in-time". These requirements includes:

1. *Just-in-time purchase*: As discussed in the introduction section, purchasing of materials for further value-adding process is better determined after the requests of customized products from customers have been confirmed. It reduces the risk of purchasing unwanted materials and inventory cost for storing them.
2. *Profit-based pricing*: Since value-adders buy and sell products at the same time, the price of products to be purchased (or sold) need not be as low (or high) as possible. As long as the desired profits can be retained, the price can be negotiated more flexibly, therefore giving suppliers or customers more beckoning prices.

The just-in-time purchase requirement is the key to dynamic supply-chain formation, since the business partnership to fulfill a demand in market is formed just in time (i.e. dynamically). Nevertheless, it should be noted that this requirement is not a must. Value-adders that buy raw products firstly, and sell customized products afterwards may still exist in the market. Some value-adders even play a passive role by selling their service directly in a service market. Three ways of doing their business includes:

1. *Just-in-time business*: value-adders try to locate appropriate suppliers when the demands from customer are confirmed.
2. *Buy-then-sell business*: value-adders buy raw product firstly, and sell customized product afterwards.
3. *Service provider business*: value-adders sell their services as products in a service market. Customers that are requesting services must bring the raw product to the value-adders.

The second and third way of doing business can be automated in current electronic marketplace, since they buy and sell independently. The focus of this paper, however, lies at mechanisms to facilitate just-in-time businesses.

3 Partnership Negotiation Mechanism for Value-adders

To achieve the cooperation requirement identified in section 2, we need a partnership negotiation mechanism that can negotiate with all potential suppliers for just-in-time purchasing. The partnership must be formed just in time when the demands from customers have been confirmed. Since price negotiation is part of a purchasing, the profit-based pricing can be achieved at the same time in the partnership negotiation. Take PC industry as example. If a computer is composed of a monitor, a mainboard and a keyboard, then an integrator needs to negotiate price with PC buyer, monitor supplier, mainboard supplier and keyboard supplier. To make sure components are purchased "just-in-time," he needs confirmations of commitments from all partners (including PC buyer and all suppliers) before he can commit. In other words, only when all partners are ready for trading, the transaction will be committed. As for the requirement of profit-based pricing, the integrator should be allowed to dynamically adjust his bedrock price during the negotiation. When the PC buyer is willing to pay a higher price (e.g. in case that they are in a hurry), the negotiating agent can raise its bedrock price for buying components, thus increase the chance of winning the components in the price competition.

Since value-adders face at least one supplier and one customer, the partnership negotiation is multilateral,. To achieve just-in-time purchase, and to guarantee acceptable profits, a value adder will need to put some customers or suppliers on hold while negotiating with others. Since there are many potential customers and suppliers negotiating, it is not possible that you can put someone on hold without paying price. Therefore we utilize the concept of options [10] from stock market, where value-adders can buy call option or put option from sellers or buyers. That is to say, if the negotiator need to put someone on hold, he buys option from him. The time been put on hold is thus compensated by the premium paid. When all partners are available and the guaranteed profits are met, the negotiator can exercise the options and commit the transaction. The underlying reputation mechanism is required in guarding these options dealing. For example, if a value-adder, as an integrator, is negotiating with three suppliers and one customer, then before he is able to commit, he can put at most three out of four on hold while negotiating with the last one to guarantee acceptable profits. If the desired profits cannot be fulfilled, the value-adder can choose not to exercise the options. The only losses are premiums, which is far smaller than the cost of buying unwanted components.

3.1 Partnership Negotiation Algorithm

Under the just-in-time purchase and profit-based pricing requirements, we propose a partnership negotiation algorithm for value-adders (PANAVA). The purpose of PANAVA is to negotiate for partnership and price under the situation where target products and available merchants have been determined. We would assume that the fundamental technologies such as agent-based electronic marketplace [12,8], market ontology and reputation mechanisms [7] have been ready, and continuos double auction (CDA) [12,20] are used for negotiation.

Let the target value-adder be VA, and there are N kinds of suppliers and M kinds of customers. For simplification, both suppliers and customers are referred as partners. When N equals to 1 and M equals to 1, VA is playing a role as transformer. Let the supplier be SP and the customer CS. The negotiation process is easy. VA can put SP on hold while negotiating with CS or the contrary.

VA needs to setup his price function for buying and selling products as explained in the Kasbah [12] system, as well as price function for buying call and put options, and a negotiation period (maximum period for holding partners). For example: A cool strategy for buying the raw product, with the negotiating price starts from 0 and ends at 200. A greedy strategy for selling the transformed product, starting from 600 and down to 300 (Figure 4). The price of options per hour is the function of negotiation time passed. The desired profits are at least 100 dollars, along with the negotiation period set to three hours.

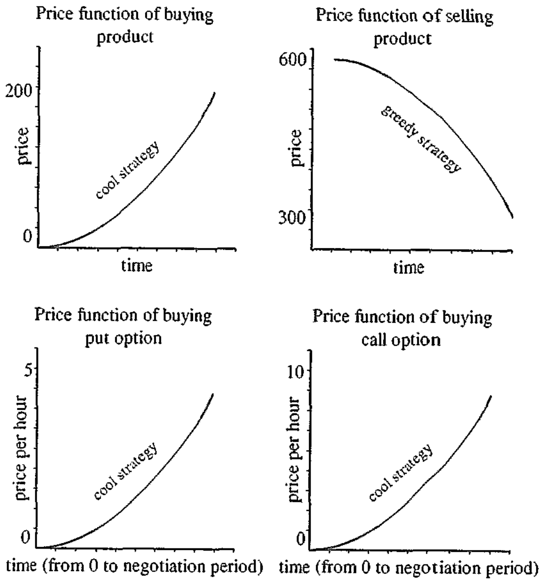

Figure 4. Examples of pricing function

Then VA starts to negotiate with SP and CS at the same time, with a simple protocol based on continuous double auctions:

```
VA: X-dollar premium for holding Y hours!
      If exercised, Z dollars to buy your produc
SP: Yes (or No).
```

```
VA: X-dollar premium for holding Y hours!
      If exercised, Z dollars to sell our produc
CS: Yes (or No).
```

If SP will sell his raw product for 150 dollars, along with 2 dollars premium for holding another two hours at end of the first hour. VA can adjust his minimum selling price from 300 to 252 when negotiating with CS for the following two hours, with the desired minimum profits still guaranteed. If CS promises a price of 280 at the end of the second hour, the VA can commit the transaction right away, with profits of 128 dollars.

For roles of integrator, disintegrator and synthesizer, the algorithm is similar. The key is to put at maximum (N+M-1) partners on hold while negotiating with the rest to guarantee the desired profits. The bedrock price can be adjusted whenever one of them has promised a price and been put on hold. For example, if there are two kinds of suppliers (SP1 and SP2) and one kind of customer (CS). The original bedrock prices for SP1, SP2 and CS are 300(maximum), 100(maximum), and 600(minimum) dollars. The desired profits would be 200 dollars or more. If a customer is willing to pay 800 dollars, and is currently on hold, the agent can modify maximum price for SP1 and SP2 to 450 and 150 dollars according to their proportion. Therefore make this deal more likely to be successful.

Buyers and sellers in this market behave differently comparing to the Kasbah system, since they accept options dealing. The motivation for options dealing, however, lies at its advantage of providing a hedge (for suppliers and customers) and a leverage (for value-adders).

The complete algorithm is expressed in the following. The negotiation detail in each market is not expressed since it has been addressed in many multi-agent negotiation mechanisms [15,20,12,8,4].

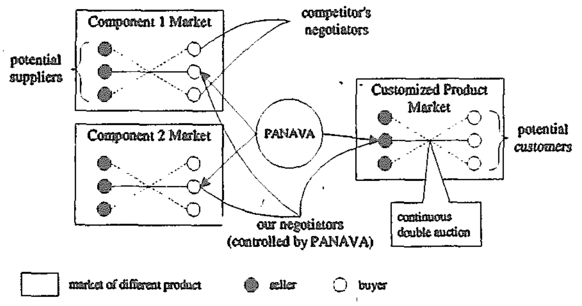

Figure 5. PANAVA

```
Initialize on-hold-list to be empty.
Place totally (M+N) partner-types in the negotiation-list;
Repeat
    If (there is only one partner-type left in negotiation-list) then begin
        If (there is already a negotiator in the correspondent market) then
            Notify the negotiator for bedrock price change and disable option dealing.
        else
            Dispatch a negotiator into the correspondent market for price negotiation.
    end
    else begin
        If (there is already negotiators in the correspondent markets) then
            Notify those negotiators for bedrock price change.
        else
            Dispatch negotiators into correspondent markets parallel for price and option premium
            negotiation.
    end.
    Wait until (one of the negotiators replied done);
    Move the correspondent partner-type from negotiation-list to on-hold-list;
    Adjust bedrock prices for other partner-types in negotiation-list accordingly.
Until (all partner-types are placed in on-hold-list) or (the negotiation period has expired);
If (all partner-types are placed in on-hold-list) then
    Commit the transaction by exercising the options;
else
    Abort the transaction without exercising the options.
```

3.2 More about Options Dealing

PANAVA works only if the mechanism for options dealing is implemented in the electronic market. But why should partners accept options dealing? When should partners accept? How the negotiation works? And what if partners refuse to discharge? These questions are explained in the following.

Partners accept options dealing because:

1. The proposed price is the best price available.
2. It is the only proposal.

Although the call or put options may not be exercised, the time been put on hold can be compensated by premiums. Therefore we believe this mechanism should be acceptable to most of the buyers and sellers. If a partner does not want to sell his options, he can turn off the negotiation channel for options dealing.

How many dollars are sufficient for holding someone a period of time? Can software agents make the decision for human? From an economic view of point, the premium should at least compensate the time blocked by value-adders. Therefore, judging from the pricing function that is setup by human, software agents can guard this condition by enforcing the negotiated premium no cheaper than the difference between current and future acceptable price (Figure 6).

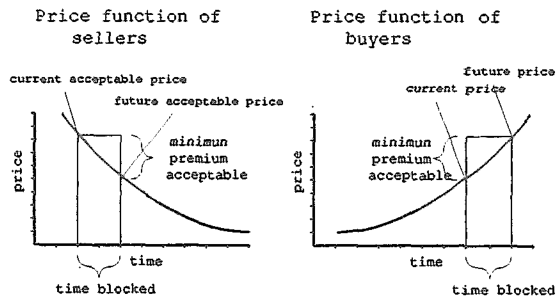

Figure 6. Minimum premium acceptable

Giving the user two more parameters, we can automate the decision:

1. Accept options dealing?
2. The minimum premium acceptable.

Parameter 2 can be specified in percentage proportional to the difference between current and future acceptable price or any number of dollars. Partners refuse to discharge their options can be punished by the reputation mechanism. Bad reputation makes them less likely to sell their options again. Recognizance may be required in some special cases, but they are not the focus of this paper.

3.3 Ways to Supply Chain Formation

The ultimate goal of this paper is to automate the formation of supply chains dynamically over Internet. Is PANAVA sufficient enough to facilitate the formation? Re-exam PANAVA in section 3.1 again, we found a problem that make supply-chain formation seems impossible. The problem lies in the assumption that PANAVA requires all partners to be ready for trading products. Nevertheless, if one of the partners is another value-adder, he will also wait for others to be ready. The supply-chain formation is then blocked. As illustrated in Figure 7, the integrator is waiting for a buyer while the transformer is waiting for a seller. The integrator refuses to integrate since he has not found any buyer yet, and the situation is same for the transformer.

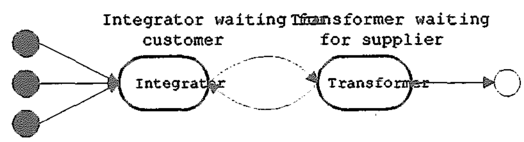

Figure 7. A partnership negotiation failure

This problem can be solved in two ways. The first one is to let value-adders delegate their rights of committing to others by selling their options. For example, the transformer in Figure 7 can sell his call option to the integrator, which means that the transformer is now playing a role as customer. When the integrator collects options from all partners, he then commits the transaction. The transformer exercises call option bought from customer when the call option he sold to integrator is exercised. Therefore the supply chain formation problem is solved. It should be noted that value-adders sell at most one option in this approach. If a value-adder sells more than one option, he will encounter problems when one of them is exercising and another not. Although this approach seems workable in all cases, it has a serious limitation: The option sold by a value-adder has time constraints that it must not exceed the negotiation period set by the value-adder. As the right of committing is delegated far and far away, the time left for negotiation is then getting less and less. In other words, as the length of the supply chain get longer, the chance that it will be committed becomes very small. Therefore this approach is not sufficient in facilitating the formation of supply chains.

Another way to solve this supply-chain formation problem is to introduce a concept of coordinator. The example in Figure 7 fails because value-adders in the supply chain are trying to solve the partnership forming problem from their own point of view. If there exists a coordinator that can coordinate the formation of this supply chain from a global view, the problem can be solved easily. To achieve this goal, the coordinator has to negotiate partnership with other value-adders for their service. In other words, a coordinator purchases services as well as raw products. This means that there are also value-adders doing service provider business as discussed in section 2.2. For example, in Figure 8, the integrator capable of integrating product D from A, B, C is selling his service in the integration service market. And the transformer capable of transforming product D into E is selling its service in transformation service market. There are customers demanding product E and suppliers selling product A, B, and C. The coordinator identifies demands in product E market, and supplies in both product markets and service markets. Therefore he forms a supply chain to satisfy the demands in product E market. He can utilize PANAVA to negotiate with product suppliers in product market and service providers in service market. Through this way, PANAVA can facilitate the formation of supply chains without modification.

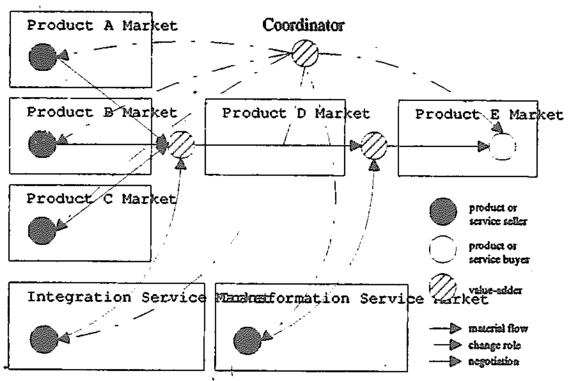

Figure 8. Coordinator and service market

To summarize, a coordinator is in fact an integrator or synthesizer that synthesizes raw products and services to produce customized products (Figure 9). Therefore the roles discussed in section 2.1 need not be changed, and so does PANAVA. We only have to allow value-adders to have suppliers that are service providers, and then the concept of coordinator can be implemented in current partnership negotiation mechanism. Since a coordinator can be a service provider too, he can be the partner of another bigger partnership formed by another coordinator. This recursive formation is conceptually workable. Nevertheless, we need more experiments to test its applicability in real life.

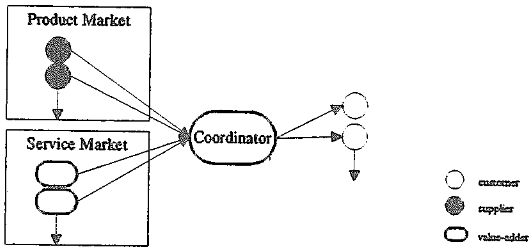

Figure 9. The service model of a coordinator

3.4 Supporting Partnership Negotiation Mechanism in an Electronic Marketplace

We have explored different business roles in a supply chain, and introduced PANAVA for partnership negotiation. A complete system architecture for supporting the partnership negotiation mechanism in an electronic marketplace is proposed (Figure 10). This architecture is based on the generalized market structure MAGNET [8], which supports multi-agent negotiation and is organized by exchange, markets and sessions.

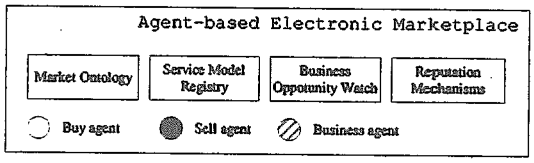

Figure 10. Partnership negotiation mechanism

Services required for partnership negotiation are listed:

1. *Buy agent and sell agent*: Both buy and sell agent should support option dealing in their negotiation protocols. Users can turn off this capability if they do not want to sell their options.
2. *Business agent*: Business agents are special agents that will negotiate partnership for value-adders. They utilize option-dealing capability to hold parties while negotiating with multiple parties using PANAVA. Business agents are dispatched by value-adders. Unlike buy and sell agents, they negotiate in different markets simultaneously as the node named PANAVA in Figure 5.
3. *Market Ontology*: Market ontology defines terms for describing the products to be traded, and terms of transactions. Option-dealing ontology should be included.
4. *Service Model Registry*: Service model registry is a place where system keeps service models provided by value-adders in this marketplace. Agents will refer to this model when negotiating for value-adders in forming a supply chain. Figure 11 is an example of service model "PC Integrator", which utilizes market ontology to define its inputs and outputs.

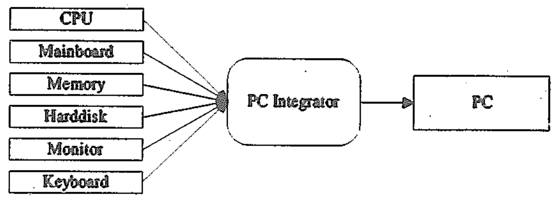

Figure 11. Service model example

5. *Business Opportunity Watch*: In our design, the marketplace can watch business opportunities for value-adders by monitoring the supply and demand in

each market. When there are demands in a value-adder's output and supplies in a value-adder's input, the system will invoke a business agent for him to capture the business opportunity.

6. *Reputation Mechanism*: Since there are possibilities that parties in the marketplace refuse to discharge their options, reputation mechanisms will be important for guarding the option dealing.

To utilize the capability of partnership negotiation, value-adders have to register their service model firstly in the marketplace. After the registration is complete, they can dispatch business agents into the marketplace for partnership negotiation. If there are currently no business opportunities (no demands or no supplies), value-adders can still dispatch sell agents into the service market. Therefore coordinators can call their services for supply-chain formation. Besides, the business opportunity watch service can withdraw sell agents and re-dispatch business agent for value-adders automatically if new business opportunities arise.

4 An Experimental System: P-Marketplace

We have developed a simple agent-based electronic marketplace called P-marketplace (Figure 12), which supports agents with option dealing and partnership negotiation capabilities. Although the business opportunity watch and reputation mechanism functions have not yet been implemented, P-marketplace provides a sufficient platform for testing PANAVA. Buy and sell agents are dispatched into P-marketplace via the Client interface (Figure 13). Users can register their service models and invoke their business agents manually through the Business Agent interface (Figure 14).

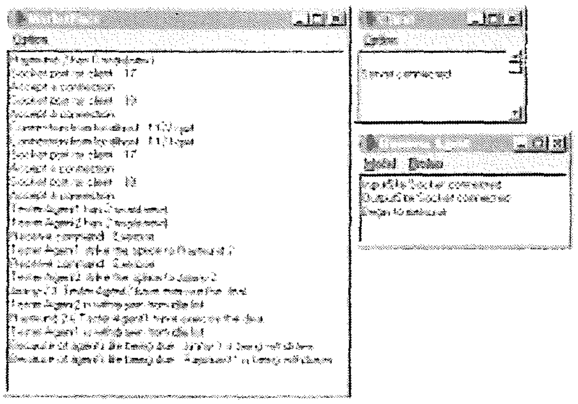

Figure 12. P-Marketplace

To simplify the implementation, the domain of market is currently limited to the computer industry. Products traded here include tuned computer, computer, mainboard, memory, CPU, harddisk, keyboard, and monitor. We include tuned computer here to demonstrate a kind of transformer called tuner, who tunes the computer by optimizing its performance. Besides tuning service provided by the tuner, PC integration service is also provided here. The service model of PC Integrator includes six inputs: mainboard, memory, CPU, harddisk, keyboard and monitor, and the output is a personal computer. A tuned PC coordinator coordinates both PC integrator and PC tuner to produce tuned computers. Its model construction using our interface is demonstrated in Figure 14.

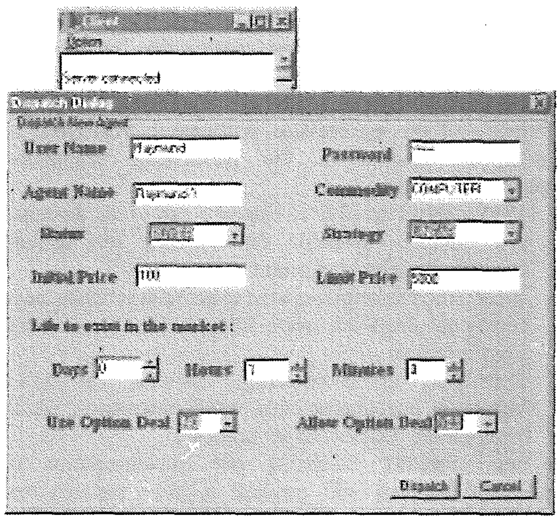

Figure 13. Dispatching a buy agent

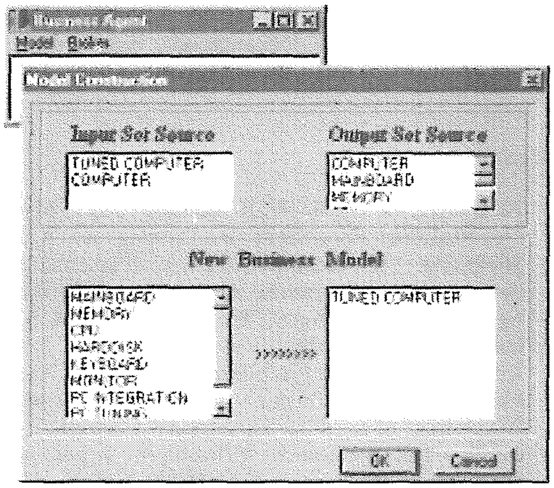

Figure 14. Model construction of the tuned PC coordinator

Experiments had been conducted to test our partnership negotiation mechanism, and results show that supply chains in an electronic marketplace can be formed automatically and dynamically. Dynamically formed supply chains contribute to an increase of deals made. Therefore, efficiency of the electronic marketplace is improved. In Figure 15, service C can transform product A into product B. With the aid of partnership negotiation mechanism, additional deals can be made.

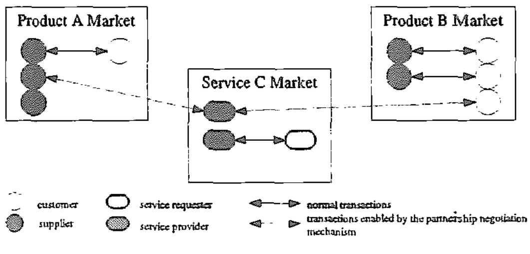

Figure 15. Increase of deals made

5 Conclusion and Future Works

In this paper we explore business roles within a supply chain, and identify their special cooperation requirements. A partnership negotiation mechanism for agents in an electronic marketplace is proposed to facilitate these cooperation requirements. Since partnerships for satisfying demands in an electronic marketplace are formed automatically and dynamically, additional deals are made. Efficiency of the marketplace is therefore improved. To summarize, benefits of the partnership negotiation mechanism includes:

1. Value-adders are able to response fast to the demands and supplies available on Internet, and capture dynamic business opportunities.
2. Electronic marketplaces tend to be more efficient since additional deals are made from dynamically formed supply chains.
3. Reduction of coordination cost in partnership formation encourages agile small enterprises, which brings more business opportunities.

We are currently enhancing our implementation of P-marketplace, and will conduct a more sophisticated real-life experiment to verify our partnership negotiation mechanism. As the real-life experiment is being conducted, exploration of business roles and their special cooperation requirements will continue. We believe the efforts devoted to dynamic supply chain formation will benefit market efficiency and agile business organizations.

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