Negotiation Protocol: Analysis based on Trading Agent Competition Supply Chain Management (TAC/SCM)

Golenur Begum Huq and Robyn Lawson
School of Computing and Mathematics
University of Western Sydney
golenur@cit.uws.edu.au; r.lawson@uws.edu.au

Abstract

Almost all businesses are involved in complex business processes including negotiation. To enter into a negotiation process, the protocol or rules of negotiation need to be established. In the negotiation mechanism, the negotiation protocol is one of the main issues in binding an agreement. This paper investigates the monotonic concession protocol, which is difficult to utilize in an automated situation such as a specified pricing formula. Therefore, we propose a non-monotonic protocol to the Trading Agent Competition Supply Chain Management (TAC SCM), which can also be used in other business processes that involve negotiation. We consider that this non-monotonic protocol will enhance the agreement-binding rate in a negotiation situation.

1. Introduction

Electronic commerce is one of the most important market places in today's electronic environment where buyers and sellers are involved in trading activities. Day-by-day electronic commerce is expanding and becoming more popular to both business organizations and consumers. However, undertaking digital business brings many significant risks. In circumstances where there are no tried and tested models, developing an e-business strategy involves ventures into uncharted waters for most managers [1].

A supply chain can include a worldwide network of suppliers, manufacturers, warehouses, distribution centers, and retailers through which raw materials are acquired, transformed and delivered to customers [2]. In recent years, new software architecture for managing supply chains at the tactical and operational levels have emerged. The traditional supply chain literature does not account for the recent development in B2B e-commerce, especially with regard to Internet-based exchanges. Thus, there is an urgent need for new models that address B2B exchanges and their impact on current procurement practices. It can be argued that the complexity of the problems, the number of parameters involved and their characteristics make simulation techniques a useful approach for solving such problems [3]. The supply chain may consist of a number of intelligent software agents in which agents are required to coordinate, cooperate and negotiate with each other, typically by exchanging messages through a computer network infrastructure. These types of integrated operations in an electronic environment are termed a multi-agent system where the agents will be representing, or acting on behalf of, users or owners who have a variety of goals and motivations. To interact successfully, these agents will require the ability to cooperate, coordinate and negotiate with each other, in much the same way that we cooperate, coordinate, and negotiate with other people in our everyday lives [4]. In the multi-agent system, negotiation does not have sufficient support for a 'binding agreement'. The meaning of a 'binding agreement' is when one or more agents jointly search a space for a possible solution through interaction with the goal of reaching consensus.

The Trading Agent Competition (TAC) provides a set of web-based multi-agent simulation environments to examine artificial e-market models and to evaluate business strategies for electronic commerce [5, 6]. At the same time TAC is focusing on evaluation of trading agents, as well as trading agent architectures, decision-making algorithms, theoretical analysis and empirical evaluations of agent strategies in negotiation scenarios [7]. As a result trading agents have become a prominent application area in Artificial Intelligence, in the large part because of their obvious potential benefits in electronic commerce. Therefore to facilitate e-business processes that involve negotiation, a negotiation protocol for applications needs to be developed.

A negotiation protocol is one of the important issues in a negotiation mechanism in which rules are determined. To strategize the negotiation mechanism towards the agent's decision-making process for purchasing components from suppliers, we analyzed the negotiation protocol in which agents can make offers and counter-offers according to the protocol.

This paper is organized in the following way: first we introduce the overview of the TAC SCM Game, then review the procurement problem of TAC SCM including supplier pricing policy. After that we discuss negotiation behaviour in TAC SCM environment. The next section provides a protocol analysis for negotiation protocol measurement. In the conclusion, the outcomes are summarized.

2. Overview of TAC SCM Game

The TAC SCM is an international competition where six software agents, that are the manufacturers of personal computers (PC) in a simulated common market economy, are linked with two markets: A *Component market* and a *Product market*.

TAC SCM is designed as a traditional supply chain model where supplier and end-users (customers) are directly involved in an electronic market. Each manufacturing agent can manufacture 16 different types of computers, characterized by different *stock keeping units* (SKUs). An SKU can consist of a combination of components required to build a PC (CPU, motherboard, memory, disk drive) and there are different versions of each component. The component types are CPUs, motherboard, memories, and hard drives. The two families - Pintel and IMD, provide CPUs and motherboard. An IMD's CPUs only matches with IMD motherboard while a Pintel CPUs only incorporate with Pintel motherboard. The CPUs are available on two different speeds like, 2.0 and 5 GHz, memories are in sizes, 1GB and 2 GB, and hard disks are in sizes 300 GB and 500 GB. There are 16 different PC configurations are available in a Bill of Materials [9].

During each TAC day of the game, customers send a set of request for quotes (RFQs) to the agents. Each RFQ contains a SKU, a quantity, due date, a penalty rate and reserve price (the highest price in which the customers are willing to pay). Each agent responds to the RFQ by sending an offer that states a price less than the reserve price. The agent that sends the lowest price wins the bid. The winning agent delivers the entire order by the due date and is paid in full if it is delivered within five days of due date. If the order is not delivered by the due date a penalty is incurred based on the number of late days. Consequently, if the agent cannot deliver the entire order within five days of its due date then this order is cancelled and the maximum penalty is applied.

On the other hand, the agents can send a RFQ to the suppliers for the required components with an expected delivery date. The suppliers respond to the RFQ the next day with either partial or full offers specifying the price per unit. A partial offer is when a supplier cannot provide the whole quantity requested by the agent, but can deliver a lesser quantity on that day. Full offers either have a delivery date on the day requested, or a delivery date later than the requested day. The agent can accept or reject these offers according to their requirements and enter into an agreement with the supplier. The agent will be charged for the components on delivery. This simple negotiation mechanism must follow when agents purchase their components from suppliers. This mechanism only focuses on the accept or reject methods.

Each agent must solve daily problems such as:

i) Bidding problems for a customer order of PCs.
ii) Negotiating a supply contract when the procurement problem deals with components that need to be purchased from the supplier.
iii) Production problems concerned with everyday scheduling.
iv) Allocation problems that deal with matching SKUs in the inventory to orders.

At the end of the game the agents receive awards based on their profit (full specification is available on the TAC site [8]).

3. Procurement problem of TAC SCM

The purchasing decision is one of the most important issues of supply chain management of the TAC SCM where the winning agent of the competition basically depends on this purchasing decision. In this context, the component prices offered by the suppliers is completely dependent on the availability of components. This creates a level of uncertainty for the agents that are placing orders for components, due to their dependence on the suppliers' pricing offer.

Suppliers set their prices for components based on an analysis of available capacity. The TAC/SCM component catalog [9] associates every component *c* with a base price *bc*. The correspondence between price and quantity for component supplies is defined by the suppliers' pricing formula.

The price offered by a supplier at day *d* for an order to be delivered on day *d+i* is as follows:

$$P(d,d+i) = P_{base}\left(1 - \delta p * \left(\frac{C_{\text{available}}(d, d+i) - \text{qty})}{C_{\text{current}}(\text{d}) * i}\right)\right)$$

Where:

- $P\,(d+i)$ is the offer price
- δp is the price discount factor and has a value 50%
- P_{base} is the baseline price of the components
- $C_{\text{current}}\,(d)$ is the suppliers capacity on day d
- $C_{\text{available}}\,(d,d+i) = C_{\text{current}}\,(d) - C_{ordered}(d)$
- *qty* is the quantity requested by the order

In SCM game, the agents purchase the components as direct material categories, that is, components used to make finished goods [10]. These direct materials are further classified into bulk purchase, critical and strategic items. The strategic items are beyond the scope of this paper as these items do not relate to SCM game. Most of the agents purchase their components as bulk on the first day when suppliers tend to have the same selling price of about 50% less when compared to the rest of the game. Some agents like RedAgent [11] and PackaTAC [12] also use the critical items that include components with long lead times and the key sourcing objective of these critical items is not low price, but ensured availability. Both agents used fairly simple offer acceptance strategies that did not reject offers on the basis of price (TAC SCM, 2003 game). The 2004 competition introduced enhancements such as: 1) the price function modified to better reflect demand; 2) storage costs introduced; and 3) customer demand segmented into multiple markets. This necessitates agents to compete with different strategies from the 2003 competition.

To increase production capacity and to sell finished products, the agents must achieve improvements, for example 'auto-activation' or 'just-in-time'. An agent needs to be tactful in: identifying market demand for the finished product; calculating how many products would need to be produced; ordering balanced components for the PCs from the suppliers; and finally bidding for a customer order of PCs.

An agent needs to maintain its competitive edge for as long as possible. This advantage allows them simultaneously to gain market share while also maintaining prices and improving production costs. Competitiveness and productivity are interrelated in the sense that the former largely depends on the latter. Therefore, it is very important that the right number of components are ordered by the agent from the supplier, and the right bid technique is applied for the customer's order.

3.1. Procurement performance of TAC SCM

The agents can order large quantities of components that will be delivered throughout the game, or separately as small quantities. Huq proposes two procurement models for TAC SCM: a) the long-run procurement, and b) the short-run procurement [13]. The first day's component ordering that involves large quantities are termed Long-run procurement, as the average prices of components are comparatively cheaper. On the other hand, the agents can order components separately for small quantities throughout the game, which is termed as short-run procurement. The short-run procurement decision for the agent is to find the output level and the associated input levels that achieve the objective it desires, that is to maximize profits. In this type of procurement, the agents should either stop purchasing, or purchase components that achieve positive levels of output. It is assumed that the agents will produce a positive output because the market price of the PC is above the minimum average variable cost. The optimum short-run procurement decision will not be stopped unless the market price is below the minimum average variable cost. The problem is that the agent always calculates its price for output as at the present time, and will sell in the future when the market price of output is comparatively cheaper, which will decrease its profit. On the other hand, if the agent wants to increase a small amount of output then, if the marginal cost is above the average revenue, then this will also decrease its profit.

For the Short-run procurement model, we can consider the agents order small quantities of components except on the first day of the game (Table 1) [13]. Generally, we found that the price of the components are more expensive than the first day. Prices can be completely uneven and uncertain due to different suppliers' availability levels of components and their adjusted pricing.

Table 1. Average price of initial and late orders for the component Pintel 2GHz Game 1131 of Semi-Final Round Gr-1

Agent	First day's Order (quantity)	First day's Average Price	Other day's (Late) Ordered	Late Average Price	Average Price of Initial and Late Order
FreeAgent:	11000	532	7	548	532
SouthamptonSCM:	14500	541	2335	681	561
Mr.UMBC:	10643	544	2675	703	576
ScrAgent:	10658	529	1000	658	540
KrokodilAgent:	12000	530	111	1110	536
Socrates:	12663	541	2200	998	608

For that reason this short-run procurement becomes risky to the agents that depend on availability of components, even though it can reduce storage costs.

From the analysis we've found that the supplier pricing formula provides a strong incentive to purchase large quantities of components on the first day of the competition, although it has been set up to reduce the inventory cost on the first day's component ordering. We have also found that the price of components on the first day was almost half or more than half than all the other days. On the other hand, sometimes it causes a dramatic delay due to huge ordering. As a result, in TAC/SCM-04 agents employed increasingly 'aggressive' first day procurement policies like TAC/SCM'03, leading to a mutually destructive overcapacity of components for the aggregate system [14]. In real world business, it is not possible to order most of the components on a specific day (like first day of game) when the price of components is cheap. Therefore, we need to optimize how the agents can purchase their components effectively, which will be sustainable.

4. Negotiations in TAC SCM

In the TAC/SCM scenario, the manufacturing agents negotiate with the suppliers in the component market and with the customers in the product market. The product market involves a bidding technique using the auctioning process.

In the component market, the agents negotiate with the suppliers through RFQs for a contract. The basic form of negotiation is no negotiation at all, which means it is a fixed-price sale where the supplier offers his components through RFQs on a take-it or leave-it basis. In the TAC SCM specification, there is limited interaction among the agents and the suppliers in the negotiation process.

To make it a more flexible and effective negotiation, a multi-issue based bargaining system needs to be developed. This involves putting forward proposals and counter-proposals until an agreement is reached or until the negotiation is aborted [15]. The bargaining technique needs to be adopted in order to capitalize on the agent's maximum utility. To create a bargaining technique firstly we need to investigate rules for the negotiation protocol to be used by the participating agents. Here we mean the utility is to obtain a maximum satisfaction for a consumer and a maximum profits for the business organizations. The next stage of this research will incorporate with the relation between non-monotonic protocol and utility function which may be used in practice.

4.1 Common issues in negotiation process

Some common issues involved in the negotiation mechanism when an agent decides to enter into a negotiation process are:

- *Negotiation Space:* All possible deals that an agent can make, that is the set of candidate deals.
- *Negotiation Protocol:* Rules that determines the process of negotiation, such as how and when a proposal can be made, when a deal has been struck, when the negotiation should be terminated, and so on.
- *Negotiation Strategy:* When and what proposals should be made. This strategy expresses a particular agent's behaviour and for this reason can be termed as private.

The following section focuses on the negotiation protocol.

5. Negotiation Protocol

A negotiation protocol is a set of rules that determine the process of negotiation. "There is no one single best negotiation protocol for all negotiation situations" [[16] p.82]. Because different negotiation rules are appropriate in different situations, any generic architecture has to support a range of rules [17]. The negotiation protocol should be public so that both parties can follow the rules. This can be introduced by the following definition.

Definition 1. (Negotiation protocol)**.** The rules that specify the whole negotiation process in which the agents come to a consensus, or come to disagreement for a specific deal.

Definition 2. (Public protocol)**.** Negotiating agents follow the same protocol if and only if it is public.

In the negotiation time, the participating agents should follow the same publicly defined protocol. Otherwise, the negotiation situation will not exist.

5.1. Monotonic concession protocol

Rosenschein and Zlotkin introduced the monotonic concession protocol [18](pp. 40-41). The rules specified in this protocol are as follows:

- Negotiation process can proceed in a series of rounds.
- At the commencement of the first round, the agents will simultaneously propose a deal from the negotiation space.
- If one agent finds that the deal matches with another agent that is asked for based on utility, then the agreement can be made. For example, if Agent 1 and Agent 2 propose the deals Υ_1 and Υ_2 respectively, such that, either: i) $utility_1(\Upsilon_2) \geq utility_1(\Upsilon_1)$; or i) $utility_2(\Upsilon_1) \geq utility_2(\Upsilon_2)$, then one agent may find its utility is at least as good as, or better than the proposal it made.

  If agreement is reached, then the rule of determining the agreement deal is considered in such a way that if both agents find their offer matches or exceeds that of another agent, then the proposal can be selected as a random basis. Or, if there is only one proposal that matches or exceeds another's proposal then agreement can be made for the deal.

- If agreement cannot be reached then the agent will proceed to the next round in which the agents begin simultaneous proposals from the negotiation space. In round $t+1$, agents are not allowed to make a proposal that is less preferred by the other agent than the deal it proposed at time t.
- If the agent cannot make any concession in a round $t>0$, then the negotiation will terminate with the conflict deal.

According to this monotonic protocol, the agents cannot backtrack, nor can they both simultaneously "stand still" in the negotiation more than once.

Theorem 1. Let Agent 1's offer be *o*1 and Agent 2's counter-offer is *co*2 against Agent 1's offer, and if the $co2 \leq o1$ which is a constantly decreasing trend, then the monotonic protocol enables the offer/counter-offer to be in a lower trend, and the opposite one is in higher trend.

Proof: Consider Agent 1 offers $20.00 for a component, and if Agent 2 does not agree with this price, then Agent 2 can make a counter-offer against it, for example $15.00. If Agent 1 does not agree on this offer, then Agent 1 can also make a counter-offer, for example $19.00 against Agent 2's counter offer. Using a monotonous protocol the agent is not allowed to make a higher offer than $20.00. Therefore, we can see that Agent 1's offer is a lower trend, which satisfies the condition of the theorem. On the other hand, the higher trend will be vice versa.

Definition 3. If the trend of Theorem 1 is replaced by $<$ then the monotony can be said to be a strict monotony protocol.

Definition 4. Agents' offers and counter-offers in the monotonic concession protocol is a linear trend.

Example: Similar to the Theorem 1, which is also a linear trend.

5.2. Non-monotonic concession protocol

Assume we want to apply a negotiation protocol in the TAC SCM for the bargaining process. According to the TAC SCM specification, supplier agents (ag_s) determine the price of components based on the supplier pricing formula (see previous section). Therefore, it is difficult to utilize the monotonic concession protocol due to the monotonic point that the agents are not allowed to propose an offer that is less preferred by the other agent than the deal it proposed before. If it is to be introduced in the bargaining process of the negotiation mechanism in the TAC SCM, then we propose a *non-monotonic protocol* to be used. For example, a manufacturer agent (ag_m) may request quotes (RFQs) for CPUs on a specified day, and the supplier agent (ag_s) offers *o* against the RFQ at price *p*. Then if ag_m makes a counter /alternating offer (Co-offer) ∂ which is less than *p*, that it is considered to be a strict monotony, which can be expressed as:

(supplier agent's offer) $ag_s(o) = p$

$$ag_m(\partial) < p \quad (1)$$

According to the economic point of view, supply and demand theory, if a customer demand *d* is high, then the price of the component will be higher, and if supply *s* is surplus then the price will be lower. Therefore, the supplier's Co-offer price may or may not be less than the manufacturer agent's (ag_m) requested price, or it can be unable to supply, or the supplier agent can reject it. This situation is considered unavoidable or special circumstances. It can be formalized as:

$$ag_s(\partial') = \begin{cases} < p & \text{if } d \leq s \\ \geq p & \text{if } d \geq s \\ 0 & \text{otherwise (that is reject } p) \end{cases} \quad \text{......} (2)$$

Because the offer must depend on the availability of components and production capacity of the supplier agent on the particular day. So, the supplier agent can propose offers which may or may not be less than the preferred manufacturer agent's deal made in a previous time. It can be more or less than the previous offer depending on current situation. As a result, offers and Co-offers are both simultaneously increasing and decreasing. Therefore, we call this type of protocol as a non-monotonic protocol. Consequently, it introduces the following definition.

Definition 5. (Non-monotonic protocol). Agents can propose any offer according to the present situation need not necessarily always propose lesser than or equal to last offer.

This non-monotonic protocol enables completely uncertain situations for the manufacturer agent. The agents will need to be able to handle this uncertain situation and make the right decision for agreement towards negotiation? Huq optimizes this uncertain situation using fuzzy logic [19]. Due to the uncertain situation, we assume that the counter-offer made by agents may not be continued for several times. Therefore, either the agreement is binding for the negotiation process and reached quickly, or can be aborted with conflict resolution. The following theorem is introduced as:

Definition 6. Agent 1 and Agent 2 can make both increasing and decreasing offers, if and only if the protocol is non-monotonic.

Theorem 2. A non-monotonic protocol facilitates the bargaining process for manufacturer agents in uncertain circumstances.

Proof: In a non-monotonic situation the price of the components will not be <u>either</u> increasing or decreasing. Let us consider that the supplier offers the price for component of $10.00, and the manufacturer agent makes a counter-offer of $6.00. Then the supplier may offer $12.00 by using the current availability and production capacity. In this way the supplier's offer may be more or less, which creates an uncertain situation in which the condition satisfies.

Theorem 3. A non-monotonic protocol ensures a supplier profit due to the price of components never goes lower than expected price.

Example: After receiving a RFQ from a manufacturer agent, the supplier agent always checks available components for the specific day and calculates the price according to supplier pricing formula. Therefore, the supplier has its full knowledge about the price of the component for the specific day. So, according the supplier's profit never goes to a lower value compared to the expected price.

Theorem 4. In a non-monotonic protocol situation, the agents either agree or disagree quickly because the situation is uncertain, and as a result the negotiation process time will be short.

Proof of this theorem is same as Theorem 2 which implies uncertainty as a result it will need less time.

On the other hand, each agent has its reserve price that is the price that the agent is ready to pay. So when the agent enters into a negotiation process it then finds the asking (offer of seller agent) price is close to its reserved price, then the agent will make an agreement and the negotiation process will end quickly. On the other hand, if the agent finds a difference between the reserve price and the asked price, which is more, then the agent will make a counter-offer until the offer is close to its reserve price. Or, if the agent finds the offered price is increasing then the agent will stop making counter-offers or make an agreement. Therefore the negotiation process will not last very long and at the same time it will enhance the agreement-binding rate. Therefore this introduces the following definition.

Definition 7. A non-monotonic protocol will enhance the agreement-binding rate in the negotiation process.

6. Conclusion

We reviewed the TAC SCM game and explored the procurement performance of agents. This game does not provide a reasonable procurement capability towards a negotiation mechanism. Again, we have investigated the monotonic concession negotiation protocol, which determines the rules in which the agents can offer and counter-offer in the negotiation process. It is difficult to use the monotonic concession protocol in the TAC SCM due to the supplier pricing formula and availability of components on a particular day. We propose a non-monotonic protocol, which can be applied in the TAC SCM game. This non-monotonic protocol is not only being applied in TAC SCM it can also be used in other automated business processes that involve negotiation. Even this non-monotonic protocol facilitates uncertain situations, though we think it will enhance the agreement-binding rate. Therefore, the negotiation process will end quickly either binding an agreement or aborting the negotiation process. The ultimate goal is to develop an efficient and automated negotiation process, which will support business organizations to avoid complex negotiation processes. Finally, it can reduce the total time for the negotiation mechanism.

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