New Multi-Agent Protocols for *M-N-P* Negotiations in Electronic Commerce

Samir Aknine

LIP6, Université Paris 6
8, rue du Capitaine Scott
75015 PARIS Cedex 15, France
Samir.Aknine@lip6.fr

Abstract.

This paper presents new multi-agent negotiation models for electronic commerce. These models address *M-N-P* negotiation problems, i.e. negotiations between *m* buyers and *n* sellers for buying *p* dependent products or services. These products or services are not necessarily provided by the same seller. We propose two new negotiation protocols as well as algorithms describing the behaviors of seller and buyer agents.

1. Introduction

Electronic travel planning is a multi-facetted problem. Currently, many Internet sites propose flights, but it is rarely possible to plan a complete trip, including hotel and car reservations -or other services- at each step. Normally, a customer sends to each travel agency a query containing travel details: number of stops, preferred date, budget, type and quality of services. Then the system must provide a package deal containing all the services required. For instance, a query "Paris-Lyon-Marseilles from the 1/6/2001 with two night stopover in a hotel in Lyon, and a car reservation for a week in Marseilles, all for a budget of $1000" must provide a set of *p* products, i.e. train or airline tickets, hotel reservation and car hire contract. This task requires the resolution of several problems: determining the itinerary, looking for different available proposals, optimizing costs, satisfying the constraints and negotiating. Therefore, such a system is an ideal experimental field for research in Artificial Intelligence, in general, and multi-agent systems, in particular. Consequently, many systems have begun to address different aspects of this problem [Anthony et al. 01][Boutilier et al. 01][Morris et al. 00][Sandholm et al. 95]. In our work, we are interested in e-commerce agents for *M-N-P* negotiations. This type of negotiation requires a special type of behavior, i.e. behavior to allow a combined negotiation between *m* buyers and *n* sellers concerning several products *p* having dependence constraints between them and which are not necessarily provided by the same seller. This kind of negotiation has rarely been studied in e-commerce, which is why it is necessary to propose several protocols to resolve the difficulties related to the constraints between the different negotiation processes concerning the *p* negotiable products.

This article is structured as follows. Section 2 analyzes related work on negotiation in e-commerce and, in particular, on negotiations with several sellers and buyers. Section 3 presents our negotiation models. The first part describes the two-phase protocol for combined negotiations and the second part the three-phase protocol for combined negotiations. Each of these phases has its own semantics and a level of penalty. The protocols are illustrated through our electronic travel application planning. Then, the negotiation algorithms adopted by each of the buyer and seller agents are presented. Section 4 concludes this work.

2. Related Work

Most negotiation protocols for electronic commerce address the problem of negotiating one product at a time under only one dimension, usually the price. [Rocha et al. 00] consider that this choice is very simplistic and not realistic in the domain of electronic commerce. Their protocol is a modified version of auctions. But even with this improvement, an auction protocol still has drawbacks which restrict its use. (1) The decision on the negotiation is centralized in the head on the auction. (2) The fact that the last proposal wins and that the buyer is committed to conclude the transaction is problematic if it is still participating in other negotiations on other products having dependence constraints with the product bought. This is the type of problem we wish to solve in our work. For simultaneous auctions, [Preist 00] presents an algorithm in order to guarantee that the agents send appropriate proposals for the different auctions in order to buy exactly the right number of products. It combines this with an algorithm determining when it is preferable to make a strong proposal in an auction that is closing, rather than to focus on other auctions. According to Sandholm [Sandholm et al. 00], when buyers wish to buy a combination of products, traditional auctions where only one product is sold at a time do not solve the problem, because the evaluation function of the products becomes strongly complex to compute.

Participating simultaneously in several auctions leads to another problem: each buyer wants to wait until the end of each auction in order to maximize its income. Therefore, it is possible that no negotiation ends. One way to correct the undesirable purchases could be to allow the buyers to sell

these products among themselves or else they could be allowed to retract, possibly facilitated by leveled commitment contracts. The protocol proposed by Sandholm consists of auctions in which buyers can send a global proposal on a combination of products. This allows them to express their wishes to buy complementary products [Sandholm et al. 00]. This approach has nevertheless two limitations: (1) it does not correspond to the case where the products are proposed by different sellers, and (2) especially, the determination of the winner of an auction on a product is a complex problem. Other researches focused on using machine learning [Stone et al. 01].

The term "combined negotiations" addresses a new type of negotiation, in which a user is interested in several products and services and engaged in several negotiations at the same time. [Benyoucef et al. 01] define the different characteristics of a combined negotiation. In their model, they consider that the negotiations are independent and can use any protocol, but the products are interdependent. They describe the architecture of CONSENSUS, their system for managing combined negotiations. In this model, they consider a negotiation as a workflow where the behaviors of the agents are formalized by rules. Nevertheless, the authors neglect multi-agent characteristics, they do not give any details on the negotiation protocol and leave it up to the user to define the protocol that suits him best for instance, a standard Contract Net Protocol.

In our case, we are interested in a different problem in which it is impossible to define a priority on the negotiations and where everything can begin or finish at the same time. They can be totally dependent, contrary to the one presented above.

3. M-N-P Negotiation models for combined negotiations

3.1. Negotiation objects

In our application, the negotiation objects correspond to different travel components: travel by train or plane between the different stops, hotel reservations for each stop and car hire for each stop. The products have several characteristics (standard of hotel, car Park, ...). Some of them can be used to define the constraints: price, because the trip has to fall within a given budget; dates, because time intervals which are allocated to the journeys and to the stopovers must not overlap.

In *M-N-P* negotiation, there are several types of dependence relation between the products negotiated. According to these dependences, buyer and seller agents decide on which negotiation model to adopt. First, product dependences are identified using the queries sent by the users, then they are formalized. In the following we are not going to detail the different possible dependence relations but will just illustrate two because the aim of this article is to present our negotiation models.

For instance, we can distinguish two types of dependence between products: strong and weak. In the case of strong dependence, the purchase of one product is conditioned by all the other products. In this case, the user formulates a query in this form: "I want to go to Marseilles for one day between 14/10 and 17/10, to stay in a hotel, for a maximum budget of $800". This query implies that the buyer agent that is associated to it must find, at the same time, a room available in a hotel for the specified time interval and train or plane ticket for the same date, with a total price within to the given limit. We cannot make any assumptions on the availability of the products sought. Furthermore, the sellers are free to apply the sale tactics and set up the negotiation margins they choose. The components of the trip are of variable importance for the user, so it is impossible to favor some elements over others (for instance, to look in priority for transport then look for the corresponding hotels).

In the case of weak dependence between products, there is a dependence relation between these products, but this relation can become an independence relation if all the constraints between the products cannot be satisfied. For instance, the user can formulate a query in the following form: "I want to go to spend a day in Marseilles between 14/10 and 17/10 and stay in a hotel for a budget of $800 maximum, but if there are no rooms available, I will accept the plane ticket". This query implies that the buyer agent must try to find at the same time a room available in a hotel for the specified time interval and a train or plane ticket for the same date, with a total price within the given limit, but in the case of failure to satisfy all these conditions, the query can be satisfied by purchasing the airline ticket. Of course, first of all these queries are formalized in logical rules so that they can be analyzed by the agents at the next step. In the following, we will only present the negotiation models that the agents use to resolve the problem of *M-N-P* negotiation for purchasing p products having strong dependences between them. These models must be adjusted to address the problem of negotiating products with weak dependences.

3.2. Negotiation protocol for combined negotiations

In this section, we will present two negotiation protocols that we propose to address the problem of concurrent *M-N-P* negotiations. In each of the two protocols, the buyer agent starts by negotiating for the p products that it wishes to buy from n sellers without having to inform them, initially, that they will participate in combined negotiations concerning the p products, i.e. that the buyer intends to buy p dependent products to form a package and that it needs each product of the package to conclude the transaction on the set of p products. The seller is informed about this later, i.e. at a certain stage of the negotiation. The first suggested protocol differs, precisely, from the second protocol in the choice of the stage at which the buyer agent informs the seller agent that it is carrying out several negotiations for purchasing p products. In the first protocol the buyer agent informs the seller agent earlier than in the second protocol that its

product will serve to form a package. The interest for a buyer agent to delay this information is that the seller agent cannot use it to increase its prices.

The protocol proposed is an extension of the one we have presented in [Aknine 98]. The author proposed a multi-agent coordination model for task allocation based on the principle of pre-negotiation between agents. The aim being to provide a solution to several problems in current coordination protocols. (1) The length of negotiations that is long, due to the sequencing of negotiation processes, an agent can only negotiate with one other agent at a time. (2) The lack of efficiency in sequential negotiations: the agent is unaware of the proposals of the other agents when it is negotiating and therefore misses opportunities. This problem is more preoccupying in the case of combined negotiations, since having an agreement between the seller and buyer on one of the *p* products adds constraints on the other products. These constraints cannot necessarily be satisfied. In the case of failure in the negotiation on one product, this will necessarily lead to decommitment of the buyer agent for all the other products as we assume that the products are strongly dependent. (3) The decommitment possibility for agents, and the penalties that they must pay. In our model of combined negotiations, we have reconsidered the decommitment strategy with paying penalties, proposed by [Sandholm et al. 95], since the value of the penalty depends on the stage at which the decommitment happens but also on the products for which the negotiations have already been totally or partially concluded.

In this protocol, we add a pre-negotiation phase that allows the buyer to check available proposals before proceeding to the transactions. Here, we have four phases: *Pre-Bidding, PreAssignment, DefinitiveBidding, DefinitiveAssignment.*

Nevertheless, as this model of combined negotiations is adapted for electronic commerce processes, we are not in cooperative negotiations as in [Aknine 98]. It is therefore necessary to check the information provided to the sellers by the buyers. If a seller knows the dependences between its proposal and those of the other sellers on the *p-1* other products of the combined negotiation, it can be encouraged to maximize its income at the expense of the buyer.

3.2.1. Negotiation protocol principle

- Pre-negotiation

In this phase, the buyer agent sends individual calls for proposals on each of the products to each of the seller agents that are likely to provide at least one of the *p* products. In response to each call for proposals sent by the buyer agent, the seller starts by sending a proposal for the product. At this point, the proposal does not commit it. Next, it can cancel its proposal without any penalties. This exchange of messages allows the buyer to be informed about the proposal of all the sellers concerning the *p* components of the travel package. If it observes that, for a given date, it receives an interesting proposal for a hotel room, it can decide that for other proposals for a room to be acceptable, they should contain this date.

- Definitive negotiation

After pre-committing themselves, sellers are warned that they are part of a wider negotiation, i.e. a combined negotiation that implies purchasing *p* products at the same time and that they have now to commit themselves with the buyer to provide the product within the given deadlines, otherwise they will have to pay a penalty which is decided according to the consequences of this decommitment. Withdrawals set off a chain reaction when at least one of the sellers retracts.

3.2.2. Communication primitives

The communication primitives used by seller and buyer agents during a negotiation to exchange information needed for the transactions are:

- Primitives of the buyer agent

The buyer uses the primitives *Cfp, Pre-Accept, Pre-Reject, Reject-and-new-Cfp, Def-Accept, Def-Reject* and *All-Reject.*

- *Cfp* "Call for Proposal" *(Buyer, Seller, Required Product):* the buyer sends this message to a seller to inform it that it wants to negotiate a product for which it gives the specifications. The buyer agent references only one product in a call for proposals in order to conceal initially the possible dependences between the products that it is looking for.
- *Pre-Accept (Buyer, Seller, Pre-Bid, Required Product):* with this message, the buyer informs the seller that its "*Pre-Bid*" proposal may be accepted and that it is included in a wider negotiation. In the "*Product*" field, it gives the characteristics of the product that it is looking for, thus giving this seller the possibility to improve its proposal. It is at this time that the seller agent knows that it is participating in a combined negotiation. The seller is not yet committed and can withdraw without paying a penalty. The strategy of delaying the announcement of a combined negotiation is important for the buyer agent because this lets the buyer know the value that the seller has defined for its product before it knew that the buyer had a strong need for this product in order to conclude the combined negotiation of the *p* products.
- *Pre-Reject (Buyer, Seller, Refused Pre-Bid, Accepted Pre-Bid):* the buyer uses this type of message to inform the seller that its "*Refused Pre-Bid*" proposal, is *Refused* and that another "*Accepted Pre-Bid*" proposal has been pre-accepted but that it cannot be accepted until it produces a better proposal than the one accepted.
- *All-Reject (Buyer, Seller, Refused Pre-Bid, Accepted Pre-Bid):* this message indicates for the seller that the buyer has not found any satisfactory proposals. It therefore rejects all the proposals and indicates the best *Refused Pre-Bid* to allow the sellers to improve their proposals.
- *Reject-and-new-Cfp (Buyer, Seller, Pre-Bid, new Cfp):* the buyer sends this message after having observed that the *Pre-Bid* that it had previously accepted is no longer compatible with the constraints of the other products. It therefore

cancels its acceptance and sends a new more appropriate call for proposals.

- *Def-Accept (Buyer, Seller, Def-Bid):* the buyer has definitively accepted the proposal of the seller, and the negotiation is henceforth closed.
- *Def-Reject (Buyer, Seller, Pre-Bid):* with this message, the buyer definitively rejects the proposals of the seller and ends the negotiation.

- *Primitives of the seller agent*

The seller uses the following primitives: *Pre-Bid, Refuse, Def-Bid.*

- *Pre-Bid (Seller, Buyer, Cfp, Proposed Product):* the seller sends this message to the buyer to present a description of the product that it wants to sell. This description does not commit the seller for the moment.
- *Refuse (Seller, Buyer, Cfp):* with this message, the seller indicates that it is not able to meet the expressed conditions in the *Cfp* and that it therefore has no proposal to make.
- *Def-Bid (Buyer, Seller, Cfp, Product):* with this message, the seller confirms its proposal (possibly improved) and commits itself to providing it. A decommitment will be punished with a penalty which is computed by taking into account the fact that the seller already knew that the buyer is in a combined negotiation.

Let us now consider the algorithms applied by the agents. These algorithms are summarized in the graphs below. Remember that in our work, we are interested in the negotiation of *m* buyers, several sellers *n* for purchasing several products *p* which are not necessarily provided by the same seller and knowing full well that these *n* sellers can receive simultaneously other calls for proposals from other buyers and that these can influence their final decisions.

3.2.3. Agent behaviors

In the following, we will simply describe the behaviors of each of the seller and buyer agents. It appears that due to the dependences between the products, the behaviors of the agents have to be more sophisticated than in classical negotiation to purchase a single product, several units of the same product [Yokoo et al. 01][Morris et al. 00][Rocha et al. 00], or several products with the same seller as is the case in [Sandholm et al. 00].

- Behaviors of the buyer agent

The buyer has initially to fill a package of *p* different products having constraints between them. It knows *n* sellers that it contacts and tries to fill its package with their proposal. It therefore sends a *Cfp* to each seller that it considers likely to provide one or more required products. Initially, the sellers ignore the fact that their negotiation is part of a combined one, even if certain sellers may receive several *Cfp* on several products from the same buyer. The buyer is now in state 1 (cf. figure 1) and is waiting for the *Pre-Bids* of the sellers it has already contacted.

If among the answers of the sellers it finds at least *p Pre-Bids* which correspond to all the components of the package, it goes to state 2 in order to compute them. If all the sellers reply with a *Refuse*, the negotiation finishes with a failure.

But if the buyer receives *q Pre-Bids* which correspond to less than the number of *p* products, and *Refuse* messages for the others, it will attempt to modify its initial query with the intention of completing its package. In this case, it goes to state 5 where it sends another *Cfp* to the agents able to provide the products that are lacking. If it cannot, it sends a *Def-Reject* to all and closes the negotiation. Otherwise, it goes to state 6 in which it waits again for *Pre-Bids*. If, in state 6, it again receives *Refuse* messages for certain of the new *Cfp*, it goes back to state 5.

If it receives enough *Pre-Bids* to fill its package with the *p* products, it goes to state 2 and computes them. In this state, the buyer uses its strategy to analyze all the proposals received. With these *Pre-Bids*, it tries to build a global proposal which corresponds to its package, respecting the constraints imposed because of the dependences between the *p* products. If it succeeds, for each component of the package it sends a *Pre-Accept* to the seller that has made the best proposal, and *Pre-Rejects* to the others. It therefore sends *p Pre-Accepts* and informs them that the negotiations are combined. Then it goes to state 3 in order to wait for the *Def-Bids*. If it does not succeed because the proposals are incompatible, it sends *q Pre-Accepts* to the proposals that it selects, *Pre-Rejects* to competing proposals for the same product and *All-Rejects* to the others. It then goes to state 7 in order to wait for *Pre-Bids* from the sellers which have received an *All-Reject* message.

In state 7, the buyer waits for the *Pre-Bids* that will allow it to complete its package. If it receives *Refuse* messages, it goes to state 8 in order to modify its package. Otherwise, if it receives enough *Pre-Bids* for its package, it goes back to state 2. In state 8, the buyer sends the *Cfp* again so that it obtains more interesting results. It can, for instance, relax its constraints in order to have sufficient choice and leave a bigger margin for the sellers. It can also completely modify certain components of the package. Therefore, certain *Pre-Bids* that have received a *Pre-Accept* answer may have to be cancelled. In this case, the buyer sends them a *Reject-and-new-Cfp* – as it does for those which have previously received a *Pre-Reject* – which means that the current package has been cancelled and that a new one has been opened. The buyer goes next to state 8 to wait for new *Pre-Bids*. In state 3, the buyer now waits for proposal that commit the seller. If a seller which has received a *Pre-Accept* withdraws – or does not reply after a certain time – the buyer goes back to state 8 in order to check if it must modify its offer or cancel certain *Pre-Accepts*. Otherwise, the buyer must receive *p Def-Bids* and eventually *Pre-Bids* from other sellers that want to improve their proposals. It computes these messages in state 4.

In this state, the buyer analyzes the *Def-Bids* and eventually the new *Pre-Bids*. If a *Pre-Bid* seems better than the *Def-Bid* corresponding to the same product, the buyer sends a *Pre-*

Accept to its sender and a *Pre-Reject* to the seller which is no longer pre-accepted. Then it goes to state 3 where it waits for the *Def-Bid* of the new agent. When it receives a *Def-Bid* from each of the *p* pre-accepted agents, it sends them a *Def-Accept* in which it informs them that their proposals have definitively been accepted and that all negotiations concerning the *p* products are closed. The other sellers receive a *Def-Reject*. The negotiation finishes successfully.

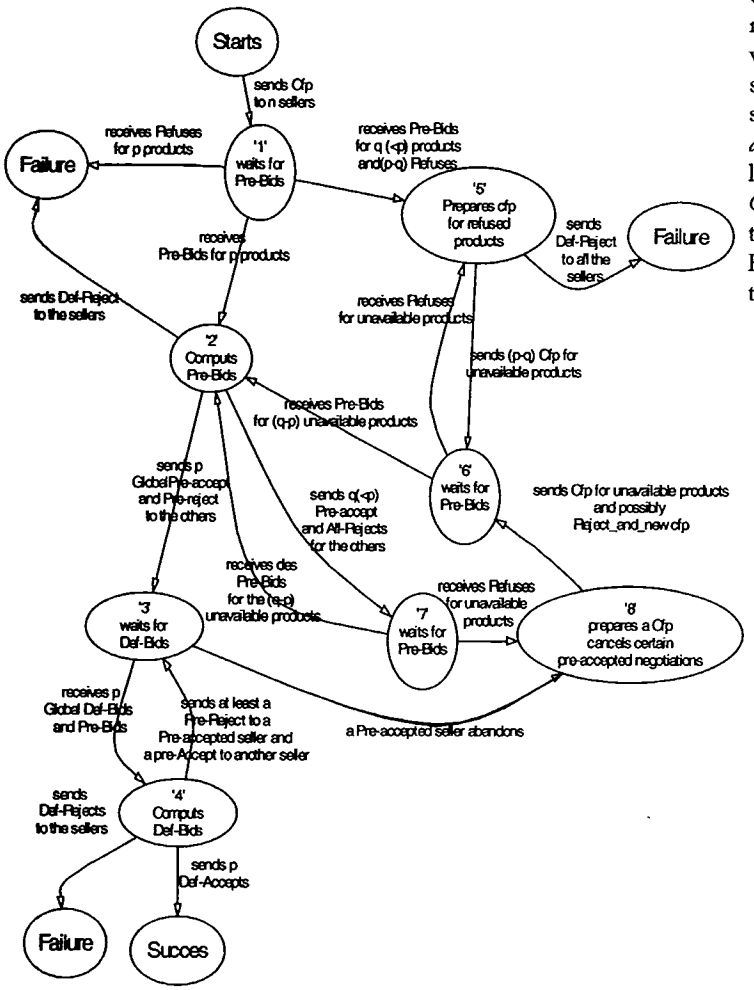

Figure 1. Behaviors of a buyer agent in a two-phase combined negotiation process

- Behaviors of the seller agent

Symmetrically, the seller is initially waiting for a *Cfp* from the buyers. As soon as it receives a *Cfp* for purchasing a product, it analyzes it and goes to state 1 (cf. figure 2).

In this state, the seller prepares its *Pre-Bid*, or sends a message of the type *Refuse* if it considers that it is not able to meet the specified conditions. In this case, it goes to the initial state to wait for a new *Cfp*', or a *Def-Reject* that will close the negotiation. If it considers itself able to satisfy the specifications, it sends its proposal in a *Pre-Bid* and goes to state 2 to wait for an answer.

In state 2, the seller waits for the buyer to react to its proposal. If it receives a *Pre-Reject* or an *All-Reject*, it returns to state 1 and tries to produce a better proposal. The negotiation ends if a *Def-Reject* is received. If it receives a *Pre-Accept*, it goes to state 3 and prepares a proposal that commits it after having received the information that the negotiations are combined. It is its last opportunity to withdraw without paying a penalty. It follows the negotiation, sends a *Def-Bid* and goes to state 4 to wait for an answer. In state 4, a *Def-Reject* closes the negotiation. Otherwise, a *Reject-and-new-Cfp* indicates to the seller that its proposal is no longer acceptable, so it goes to state 1, as it now has a new *Cfp* to analyze. If the agent receives a *Pre-Reject*, it also returns to state 1 in order to attempt to make a better proposal. Finally, if it receives a *Def-Accept*, the negotiation closes with the transaction.

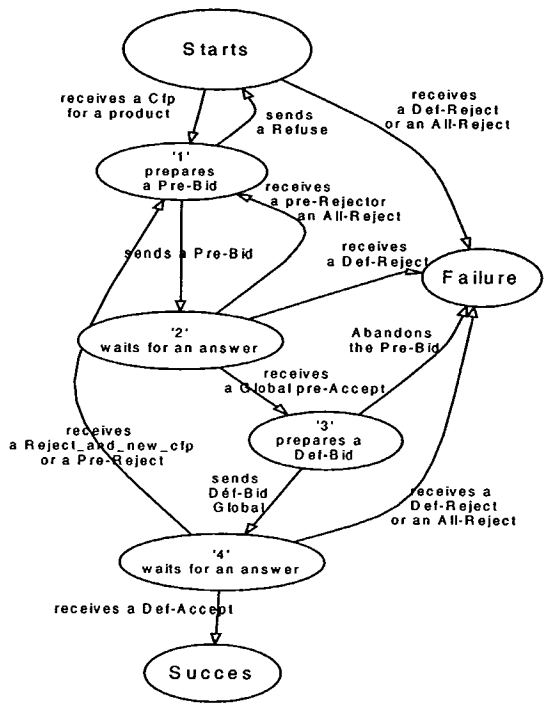

Figure 2. Behaviors of a seller agent in a two-phase combined negotiation process

In order to guarantee the convergence of the algorithm, it is possible to apply several strategies. In our case, we attribute a limited time to the negotiation. When the time for the pre-negotiation phase is up, the agents that wish to remain in the negotiation can only send *Def-Bids*. *The buyer* just sends *p Def-Accepts*, or *Def-Rejects*, to close the negotiation.

3.3. Extending this protocol

In the two-phase protocol, sellers are informed that their proposal is part of a combined negotiation as soon as they

receive the *Pre-Accept* from the buyer for their product, and they are then free to use this information in their strategy. For instance, an airline company can increase the price of its flights for a given date if it observes that the buyer is interested in this date. If the buyer negotiates other services for this date, it will certainly prefer to accept more costly proposals from the company than to reject them and risk not finding services available for another date. The aim of this extension (three-phase protocol) is to avoid this drawback for the buyer, unlike the two-phase protocol where the seller agent knew that it was part of a combined negotiation after sending a *Pre-Bid* but before committing itself with a *Def-Bid*. This protocol behaves so that the seller makes an initial commitment on the product, before knowing that it is participating in a combined negotiation. This commitment obliges it to provide the product that it has agreed to sell during the previous phase and to pay a local penalty, i.e. computed on the product, if it withdraws. When the seller is informed that the negotiation is on p products, it can make a stronger commitment than the previous one, i.e. a commitment that takes into account the fact that the buyer must have a package where all the p products are satisfied. This commitment allows it to renegotiate the *Def-Bid* that it has already sent and therefore to improve it. However, in this case it also agrees to pay a global penalty, i.e. a higher one because it is computed on the set of p negotiated products, if it withdraws, since its withdrawal would put into question other transactions, i.e. those on the p-1 other products. It can also limit itself to the first weak commitment that it has accepted on the product. This negotiation protocol gives a better result regarding the quality of the solutions compared with the previous protocol. However the negotiation needs more time.

4. Conclusion

Currently, several multi-agent negotiation models for electronic commerce exist, but few of them address the problem of purchasing p different products not necessarily provided by the same seller. For this reason, we have proposed two new negotiation models to take this requirement into account efficiently. These models are based on two or three negotiation phases. The two protocols can check if the fact that a seller knows it is participating in a combined negotiation has a determining influence on its strategy. Each of the protocols is illustrated through an electronic application for travel planning. We have proposed negotiation algorithms applied by each buyer and seller agent. In current work, we are addressing some related problems: (1) the formalization of all dependence relations between products and the definition of negotiation protocols which correspond to them; (2) the computation of the penalties to be paid by each buyer and seller agent when using these protocols. These penalties are computed differently compared with a traditional *M-N* negotiation. In combined negotiations with several sellers, the decommitment for a product involves a chain reaction of decommitments on the other products due to dependence relations between the products, (3) we intend to compare the results of this model to another agent coalition formation model which we have proposed in previous work [Caillou et al. 02]

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