Towards an Agent-Based Approach for Multimarket package e-Procurement

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Abstract

While most e-commerce research focuses on one market based problems, less work has been done on multimarket aggregation. Nowadays it is important to address the multimarket package e-procurement problem if we want to acquire a combination of goods and services from different suppliers and service providers. To achieve this, one should address the issues pertaining to identifying of a company's needs, discovering potential partners and suppliers, gathering distributed information and conducting combined negotiations, creating a seamless of information flow with different heterogeneous markets, suppliers, and partners, and finally concluding transactions. Several commercial e-procurement applications already automate some aspects of the procurement processes, helping decision makers and employees complete their purchasing activity. But none take into account the key aspects of combining goods and services into one aggregated package. Agent-based systems are well equipped to address the challenges of multimarket package e-procurement. Indeed, goal driven autonomous agents aim to satisfy user requirements and preferences while being flexible enough to deal with the diversity of semantics amongst markets, suppliers, service providers, partners and individual sellers. A distributed common shared space, called infospace, comprised of the negotiation exchanges and states, allows for agent coordination, market aggregation, and packages construction. This paper presents some issues and challenges faced in multimarket package e-procurement, and puts forward an agent-based approach to deal with them.

Keywords Markets, e-Procurement, Combined Negotiation, Multiagent Systems.

1. INTRODUCTION

The multimarket package procurement of goods and services can be defined as the procurement of a package of interdependent items and services from various heterogeneous sources —electronic marketplaces, providers of goods and services, and individual sellers— while best satisfying user constraints and preferences. Autonomous agents are well equipped to address the complexities involved in tracking these external sources, gathering distributed information, as well as coordinating and monitoring multiple parallel negotiations. In this paper, we propose an agent-based approach for multimarket package e-procurement. In this approach, coordinator agents receive a package of items that should be acquired and are responsible for the succesful completion of this activity. The steps it must supervise are information searches, combined negotiations, and transaction processes (see section 3.1). On the other hand service agents act as gateways to the various external actors (see section 3.2). These agents use a distributed space we call infospace to share information. In its current form, this infospace is a shared virtual marketplace used by the agents to communicate by publishing goals and responses.

This paper is organized as follows. Section 2 presents the multimarket package e-procurement problem. Then, Section 3 discusses the value of an agent based approach. Finally, Section 4 takes a closer look at our proposed architecture.

2. MULTIMARKET PACKAGE E-PROCUREMENT PROBLEM

2.1 e-Procurement Phases

In the B2B area, the e-procurement problem includes the following phases (see figure 1) [1] [2] [3]:

- Requisitioning: identifying the purchasing needs. This step may be accomplished by production analysts, decision makers or employees, or may be automatically generated by an Enterprise Resource Planning application (ERP). The needs of a company may vary from long term strategic products supplying of raw materials to spot purchasing of indirect goods like a new computer for the CEO's secretary.
- Sourcing:
  - Finding potential suppliers and/or partners that can satisfy the identified needs. This is a preliminary phase to the final selection of suppliers and/or partners.
  - Submitting requests for information (RFI) and/or requests for quotes (RFQ). Requests may ask for prices, availability, quantity, quality, delivery time, etc.
  - Comparing and evaluating offers and/or opportunities, and selecting the most promising suppliers. The evaluation function may be very complex. Moreover, it may take into account non-rational attributes like the degree of trust in one supplier. The selection phase may be accomplished using historical data about suppliers from a Supplier Relationships Management application (SRM).
- Negotiating: the negotiation process may take place with one or many selected suppliers on different markets simultaneously. The buyer may negotiate discounts on product prices, long term supplying partnership, etc. Negotiations may occur in the sourcing phase while selecting potential suppliers.
- Concluding transactions: the buyer has to put into operation a transaction workflow that usually includes purchasing approval procedures, order transmission, payment, and receipt reception.
- Supplier Relationships Management (SRM): this includes evaluating purchased services and products, and supplier's quality of goods and services, relevance, trustworthiness and cost. The SRM may help decision makers analyse purchasing data and identify weak points in the procurement strategy of the company.

Depending on the business domain of a company, some steps of the e-procurement may be less important than others. In some cases for example, a company may not need to identify potential providers for every purchase it makes, since it has partnerships with suppliers with which it deals in private e-markets. In other cases, submitting RFIs and/or RFQs, and negotiations may not be allowed, the buyer has access to suppliers product catalogues from which he chooses the appropriate products in a take it or leave it form.

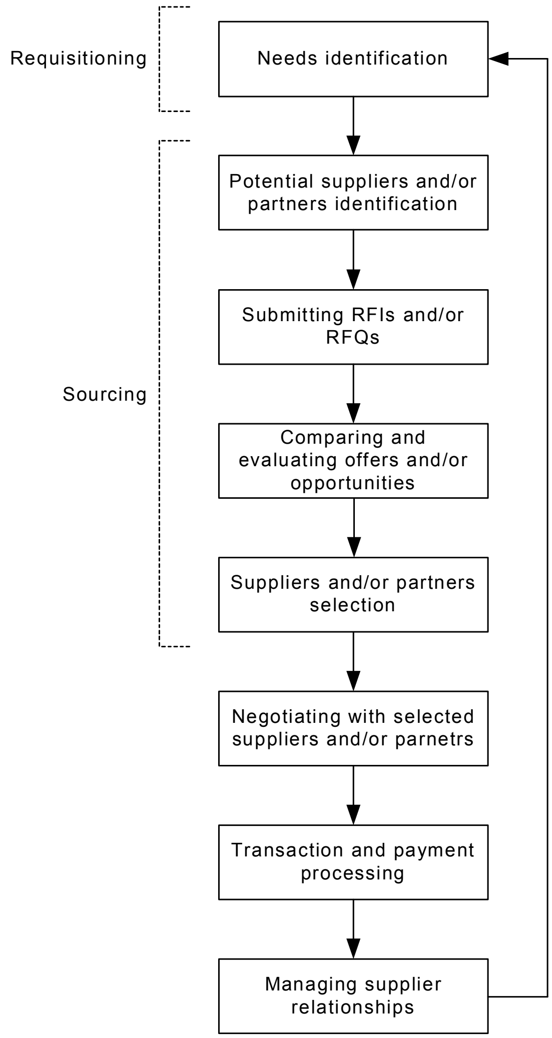

Figure 1. e-Procurement phases.

2.2 Package e-Procurement

There are a multitude of commercial applications that deal with the automation of e-procurement processes such as Ariba Buyer [4], and CommerceOne's Enterprise Buyer [5]. However, much work has to be done in the field of multimarket package e-procurement. Procuring a combination of items from different heterogeneous sources, negotiating them, and aggregating the results into one common package, is a harder challenge than just buying independent items. In this section, we describe some illustrative examples and discuss the challenges and issues in multimarket package e-procurement.

2.2.1 Illustrative examples

Here are some illustrative cases of multimarket package e-procurement:

- The multimodal transportation case. Suppose that a freight forwarding company receives an urgent request from one of its important clients who wants to ship some products overnight. In a nontrivial case, the freight forwarder needs to find different carriers to provide transportation for different parts of the route, which are the items composing the requested package. These items are heavily interdependent, since the arrival time in one transition point must correspond to the departure time from that point. Moreover, the company needs to deal with many heterogeneous markets since carriers of different modes —air and sea cargo, rail, or truck— all have distinguishing characteristics that make their markets incompatible.

- The business trip case [11]. A traveler wants to plan a business trip that includes multiple flights, hotel reservations, car renting, and special events reservations. All these items are obviously interdependent and compose the travel package.

- Telephone switching systems: Ardissono et al. [6] describe the procurement of telephone switching systems problem. Switching systems are composed of modules installed on frames which are mounted on racks. These modules determine the functionality of the system and are provided by different companies. When a telco sets-up a new system, it needs to combine the purchase of the modules mounted on a frame from different vendors with the acquisition of new frames and racks. This is a typical case of multimarket package e-procurement problem.

The fundamental issues faced in multimarket package e-procurement problem will be discussed later in this section.

2.2.2 Package Requests

The request for a package defines a combination of items that it wishes to acquire as well as some constraints and preferences. These items are often interrelated as they can have relations amongst each other —alternative (one or the other), co requisite (one and the other) or prerequisite (if one then the other). Moreover, an attribute of an item may be dependent on another's. For example when shopping for a travel package, a user might want for his plane arrival and departure time to coincide the start and end of his hotel reservation. There are also other constraints associated to the package itself. For instance, a user might specify a maximum-price constraint for his travel package. We plan on defining a formal description to model package requests (user constraints and preferences, relations between items, and attributes interdependencies).

2.2.3 Open and Heterogeneous Markets and Sellers

In the world of e-commerce, there exist different market models and mechanisms. They vary from simple take it or leave it mechanisms as in shopping sites like Amazon [7], to more or less complex auction mechanisms like those in eBay [8]. In addition, there are virtual B2B horizontal and vertical marketplaces such as oilandgasonline.com [9] and GF-X.com [10] that implement various negotiation and sourcing mechanisms (usually auctions for sellers and reverse auctions for buyers). Finally, in some sectors, information can only be accessed by interacting with a human and require e-mail based request for quotes (RFQ) and negotiations.

In order to interact with various heterogeneous markets, the information flow should be shared and processed in standardized formats. Using a virtual market paradigm would be appropriate to support such interactions.

2.2.4 Combined Negotiations

In the multimarket package e-procurement process, a buying company may be involved in a combined negotiations in order to acquire the items composing the package. A combined negotiation (CN) is the conciliation of multiple negotiations in order to build packages that satisfy both item interdependencies and packages constraints. To describe a negotiation space, Jhinigran proposes a three-dimensional model in [12] that was extended by Benyoucef and al. with a multiple negotiation dimension [13] (see figure 1). The 'multiple copies' dimension represents a negotiation on a quantity of identical items [14], the 'multiple items' dimension stands for a negotiation on different items, the 'multiple attributes' addresses negotiations on different item attributes (colour, quality, etc.), and finally the 'multiple negotiations' dimension deals with cases where more than one negotiation are simultaneously run.

In a CN, dependencies between the requested items mean that the results of a negotiation (failure, success, winning price and quantity, etc.) may have repercussion on other negotiations. These relations between negotiations should be formalized and described, as they are in the rules and workflow based description of a CN defined in [13].

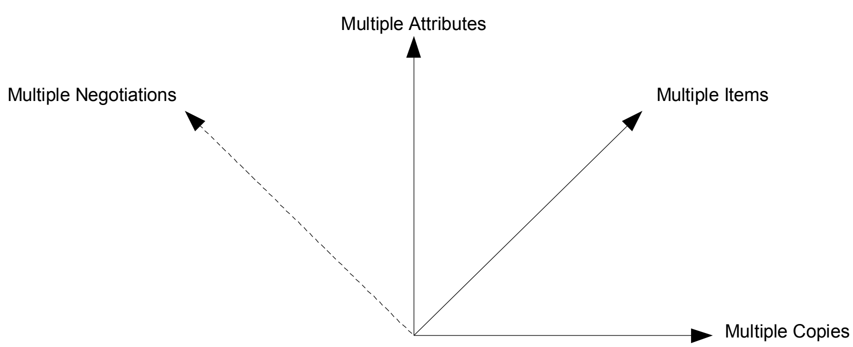

Figure 2. The four-dimensional negotiation space.

3. COORDINATOR AND SERVICE AGENTS

At least, two fundamental levels seem to be crucial in an agent-based approach to deal with the multimarket procurement problem: the coordination level and the service level.

3.1 Coordinator Agents

A coordinator agent is responsible for the management of a multimarket procurement request. Figure 3 presents the coordinator agent architecture that we will present in this section.

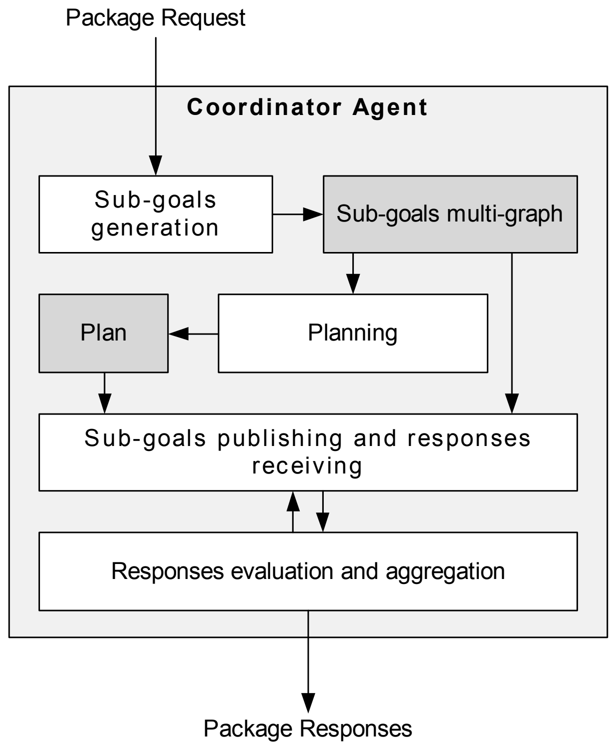

Figure 3. Coordinator agent architecture.

3.1.1 Creating Structured Sub-Goals

The first task of a coordinator agent is to extract a global goal from a company request for a package, then decomposes it into sub-goals, each corresponding to the task of obtaining an item of the package. The decomposition of user requests is not a simple task since users might not explicitly ask for a complete and well-defined combination of items. In order to be able to process an incomplete request, the agent needs to extrapolate implicit sub-goals of a package using its knowledge of the application domain. For example, in the travel package problem, if a user requests a vacation package leaving Montreal and visiting Paris and London, the coordinator agent should be able to decompose the request into sub-goals: negotiate a transatlantic flight, local transportation between requested destinations (by bus, train, ferry, domestic flight, or rental car), hotel reservations, and other package items like tickets for concerts.

The agent should arrange the sub-goals in a structured manner, taking into account the dependencies and relations between the package items. We propose to structure sub-goals into a multi-graph (a graph with one or many arcs between two nodes) where the arcs encapsulate the sub-goals. This structure will enable us to express AND/OR relations between sub-goals.

Let's suppose for example that a traveler wants to buy a roundtrip travel package From Montreal to Paris, including a hotel reservation in Paris. This initial goal may be decomposed into these sub-goals :

```
(Roundtrip flight from Montreal to Paris with Air Canada) OR
(Roundtrip flight from Montreal to Paris with Air France))
AND
((Hilton hotel reservation in Paris) OR
(Mariott hotel reservation in Paris))
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may be represented by the multi-graph of figure 4 where the node in the middle expresses the AND relation, while the multiplicity of arcs between two nodes expresses the OR relation.

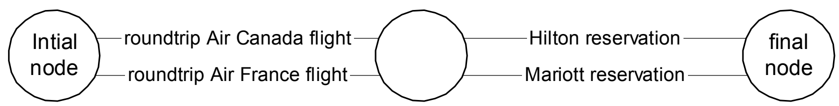

Figure 4. Structured representation of sub-goals into a multi-graph.

3.1.2 Planning the Information Retrieval Process and the Combined Negotiation

Once sub-goals are extracted and structured into a sub-goals multi-graph, the agent has to plan the execution of requests for these sub-goals. At this point, the coordinator decides which ones should be published in parallel, and which ones should be published sequentially. In the travel package example shown in 3.1.1, it is obvious that it should look for transatlantic flights availability before looking for hotel reservations. This decision may be driven by the fact that information about transatlantic flight schedules and prices is readily available, and does not require it to make any commitments.

We propose to implement this planning function using a rule driven approach. Rules may be introduced by specialists from the purchasing department of a company. Thus, the human purchasing strategy may be automated using such approach. In the example of 3.1.1., a rule that may be applied would be:

```
IF    looking for roundtrip flight
AND   looking for hotel reservation
THEN  look for flight availability
      IF there are some flights available
      THEN look for hotels
```

We think that rule engine applications like Jess [15] or Ilog's Jrules [16] should be used here to generate information retrieval and negotiation plans. The negotiation plans may be described as more or less complex workflows depending on the application domain. See [17] for the use of workflows in electronic negotiations monitoring.

3.1.3 Coordinating and Monitoring Information Search and Negotiations

Obviously, after generating a plan, the coordinator agent will execute it. At this point, the coordinator publishes the structured sub-goals multi-graph in a shared space (see section 4), then activates the first sub-goals according to its plan. Then, it waits for responses published by service agents (see section 3.2) and attached to the sub-goals arcs. Depending on feedback from an evaluator module (see section 3.1.4), it can activate new sub-goals, desactivate previously activated ones or relax constraints on them.

The coordination is carried out using a loosely coupled publisher-subscriber model, as the agent is unaware of the entities it might interact with. It is for this reason, that it cannot be qualified as completely centralized coordination. The agent's decisions depend only on its own goal, which is to find the best solution for a requested package. We call it an implicit semi-centralized coordination.

The main issue in coordinating information search and combined negotiations is the level of commitment an agent should consider in order to grab the information about product prices, availability, quantity, etc. Benyoucef et al. [18] give two examples of problematic negotiation coordination. First, if many agents simultaneously participate in English auctions in order to purchase only one item, we have to ensure that only one agent wins his auction, preferably the cheapest one, guaranteeing that only one item is purchased. Second problematic situation examples is when many agents are negotiating different complementary items composing a package. We have to ensure that deals are made on all items composing the package thus the complete package is purchased. If we fail purchasing one item then we should have the ability to cancel the other negotiations.

We propose a classification of commitment levels in information gathering and negotiations as follows :

- No negotiation possible, no commitment required. This is the case of catalog based vendors. An agent can just access a price and availability list from which it can grab the information it needs without any required commitment. The information is supposed to be constant in time, or an delay time for information consistency is given. For example an air travel tickets vendor may inform the buyers that the information displayed in his catalog will stay the same for one week. Shopping bots is an example of agents that usually grab information from catalog based vendors. In [19] the authors propose an multi-agent architecture for search in information marketplaces.

- Negotiation possible, but no commitment required. This is the case of most one to one negotiations between companies. Negotiations consist generally in an offer counter-offer process, which may lead (or not) to a mutually acceptable situation (without required commitment).

- Negotiation required and commitment required if you win the negotiation. This is the case in most auction mechanisms. The auction winner is required to purchase the item he won. While there are some auctions where withdrawing is possible, often there is a penalty to pay if you retract after winning. See [20] for state of the art auction mechanisms description and analysis.

The proposed approach to deal with such information search and combined negotiation coordination problems, is a rule-driven approach. Here, rules define the actions to do when facing complex situations with different degrees of commitment. Such rules are presented in [18] in the fourth case described above. We are envisaging the extend such rules to all the different levels of commitment.

3.1.4 Evaluating and Aggregating the Responses

The response aggregation is a constraint satisfaction problem carried out by an evaluation module of the coordinator agent. In fact, depending on the user needs and preferences expressed in the requisitioning phase, the evaluator module generates an optimization function that will evaluate individual responses to sub-goals and aggregate them into a global response to the initial package request.

In the case where the package is composed by weakly dependent items, a computer and a computer screen for example, the aggregation is simply done by obtaining both items. However, items can be strongly dependant as in the example of the travel package where a user's transportation should drop him off at his hotel where and when he has reservations. In this situation, we are facing a more complex constraint satisfaction problem in order to find the optimal combination of responses. The evaluation of a package's responses is closely associated to and affects the coordination process.

3.2 Service Agents

Service agents are the system's gateway to external sources of goods and services. We propose an agent factory that manages the instantiation of generic agents with capabilities and knowledge necessary for interaction with external markets. These agents are aware of the source's market model and of the protocols it uses. They should be able to interact with one source, requesting information, eventually starting negotiations, and concluding transactions.

A service agent should be able to determine which requests it can service. It proactively reads these requests and tries to find an acceptable answer. Then it publishes its responses or results in a shared place (see section 4). The complexity of these agents can vary tremendously as we can have simple translator slaves as well as sophisticated agents, which carry out complex negotiations.

4. MULTIMARKET AGGREGATION: THE INFOSPACE

The main idea behind multimarket aggregation is the concentration of shared information, negotiation and agent states into one common virtual market that we call infospace. It is here that we find the sub-goals' multigraph and the requests published by the coordinator, as well as the responses given by the service agents.

The infospace is in fact an instance of an Linda-like tuple space [21]. The advantages of using Linda-like coordination have been analysed in the field of mobile agent coordination [22]. There are two important reasons that we believe that an tuple space is the optimal coordination mechanism for our procurement agent solution. First of all, the associative access mechanism encourages temporal and spatial uncoupling. This uncoupling allows a flexible goal publishing where a goal can be published without knowing if and when an answer will come and who might answer it. Interested agents can use the pattern matching properties of the space to locate goals they can service. In the proposed architecture, we can imagine a coordinator agents publishing the goal of verifying an availability of a package item. In this scenario, all the appropriate service agents interested in the item will attempt to accomplish the goal. Secondly, the tuples of a space [23] can collectively form complex datastructures because the elements composing these structures are independent of their creators. These two properties permit the creation of a graph coordination structure where agents can listen for the publication of new arcs that represent goals they can accomplish. In addition to the classic Linda operations (in, out, read), the infospace also offers distributed notification capabilities. Every agent has capacities to register with the infospace to be notified every time there is a specific type of goal published. The service agents should be notified when goals involve communicating with external sources while coordinator agents should be notified when a service agents post results.

We can see the infospace as a metaphor of a one buyer many sellers e-market, where participants are not human but software agents. The coordinator agent is a buyer, and service agents are sellers. The coordinator agent acts like a human buyer : identifying its needs (the sub-goals multi-graph creation), publishing requests and receiving responses from sellers (service agents), choosing the best responses and aggregating them, eventually negotiating better responses, and concluding transactions.

We are trying to implement a generic infospace using Sun's JavaSpaces technology [24]. A JavaSpace is a shared memory that allows distributed processes to write and read objects as entries. A process may register into a JavaSpace with a specific template in order to be notified every time a written entry in the JavaSpace matches that given template.

The metaphor of a virtual aggregated market exchange board between all agents is illustrated in figure 5.

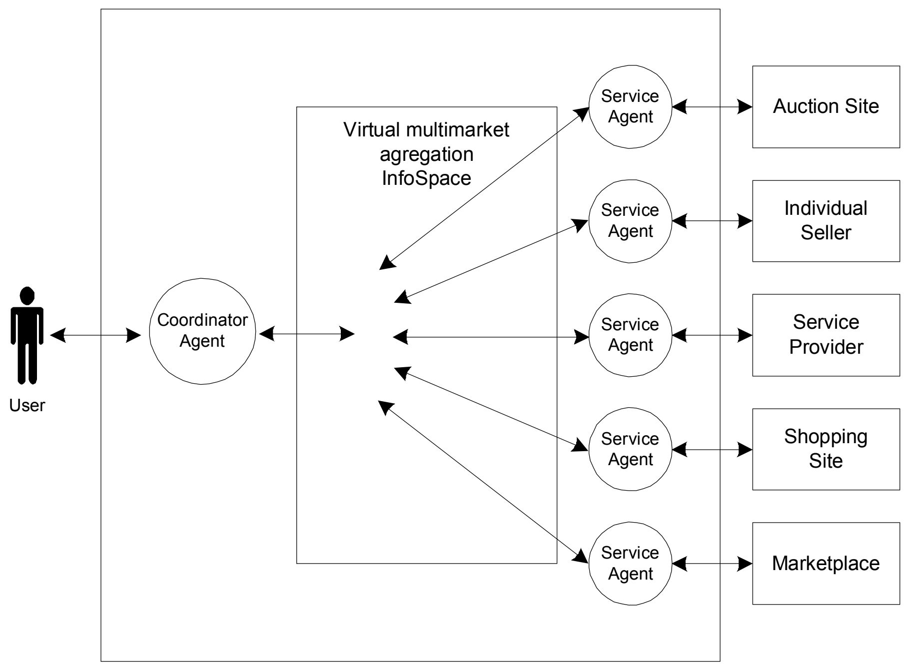

Figure 5. Multimarket aggregation.

5. CONCLUSION AND PERSPECTIVES

The multimarket package e-procurement problem is rich of challenges and complex issues. They include:

- Expressing a formal description of user needs and preferences for a set or package of related items or services,
- Expressing a formal description of item and service providers' characteristics, protocols and models,

- Describing application domains,
- Decomposing user requests into structured sub-goals,
- Planning, running and monitoring information retrieval and combined negotiations with multiple heterogeneous providers,
- Handling dynamic discovery of the appropriate providers that may satisfy a user demand,
- Dynamic creation and instantiation of service agents,
- Evaluation and aggregation of responses.

We do not pretend that our approach offers general solutions to solve these problems, but we believe we have a solid grasp of the complexities involved in building a multimarket e-procurement system. A key point to remember is that when implementing a specific domain application for a multimarket package e-procurement problem, some issues are more important than others. This requires further in-depth studies of the application domains. For example, in a multimodal transportation problem, we do not have to deal with dynamic discovery of providers, since transportation companies and e-marketplaces are well known and don't appear and disappear every day. More important however, is the decomposition of a user transportation request into sub-goals and the response evaluation, for we need to deal with large quantities of information.

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