Mobile Agent System for Supply Chain Management

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Abstract—In the 21st century, competition between companies has been turned into the competition between their supply chains. To satisfy the rapidly changing demands in global market, agile capability and flexibility have become the new requirements in today’s Supply Chain Management (SCM). Some intelligent activities, such as negotiation, decision and collaboration, have become the “bottleneck” to improve the performance of SCM. This paper first discusses the development of mobile agent and explores its application in SCM, and then presents a mobile agent system for SCM in the case of flower trading. It can deal with the negotiation, decision and collaboration intelligently and automatically.

I. INTRODUCTION

The primary objective of Supply Chain Management (SCM) is to fulfill customers’ demands through the most efficient use of resources, including distribution capacity, inventory and labor [1]. Nowadays, customers become more demanding in competitive and global market. A single enterprise is no longer capable to deal with the fast changing and customized demands, so the SCM-based alliance is becoming the mainstream of business organization in the 21st century. Therefore competition in today’s market is no longer of company versus company but rather the supply chain versus supply chain [2]. The performance of SCM has become the decisive factor to satisfy various demands with the lowest cost.

A supply chain is a system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer [3]. The performance of SCM depends on the efficiency of complicated collaboration and integrated management in the whole of supply chain. Information technology, such as database, application software and communication network, has been widely applied in SCM to improve its performance. It has solved the information sharing problem and some ordinary management problems successfully, but there are still a lot of intelligent activities to be improved, such as negotiation, decision and collaboration. Especially in the dynamic business environment, agile capability and flexibility have been the new requirements in today’s SCM, and those activities have become the “bottleneck” to affect performance.

This paper explores the application of mobile agent system to deal with the intelligent activities in SCM. It first discusses the development of mobile agent and its application in SCM. With the case of flower trading, we present a mobile agent system for the SCM. It can deal with the negotiation, decision and collaboration intelligently and automatically.

This paper is organized as follows: Section 2 discusses the development of mobile agent and its application in SCM. Section 3 presents a mobile agent system for the case of SCM in flower trading. Section 4 is the conclusion of this paper.

II. DEVELOPMENT OF MOBILE AGENT AND ITS APPLICATION IN SCM

A. Mobile Agent and Its Development

A Mobile Agent (MA) is actually the hybrid of distributed computing technology and agent technology. It is a type of software agents with the features of autonomy, social ability, learning, and the most important feature mobility [4].

A mobile agent consists of three parts: code, state and data. The code is executed when mobile agent migrates to a new platform. The state is the data execution environment of the agent, including the program counter and the execution stack. The data consists of the variables used by the agents, such as knowledge, file identifiers. And there are two primary types of migration of mobile agent: strong migration and weak migration [5]. Strong migration is more complex and is the case where an agent’s execution is frozen, migration takes place and then execution is restarted from the very next instruction [5]. Weak migration does not send the agent state, and agent execution restarts from the beginning of the code.

There’re already many platforms for the development of mobile agent, such as Aglets, Ajanta, JADE, and Voyager. Due to the features of JADE, we choose it as the mobile agent development platform. JADE is a software platform that provides basic middleware-layer functionalities. It contains two parts: a platform for agent following FIPA standard, and a software package for Java agent development. A significant merit of JADE is that it

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implements this abstraction over a well-known object-oriented language, Java, providing a simple and friendly API [5]. Figure 1 is the reference architecture of agent platform following the FIPA standard.

![Figure 1. Reference architecture of agent platform following the FIPA standard](image)

JADE platform is composed of agent containers that can be distributed over the network. Agents live in containers which are the Java process that provides the JADE run-time and all the services need for hosting and executing agents. We can consider agents as objects, but agents have some special traits: they are autonomous (i.e. they decide for themselves whether or not to perform an action on request from another agent); they are capable of a flexible behavior; and each agent of a system has its own thread of control [6].

Agent Management System (AMS) and Directory Facilitator (DF) are parts of the platform. There’s only one AMS on one platform, which offers the white page service and agent lifecycle service, and maintain the directory of agent identifiers (AID) and the state of agent. DF offers the yellow page service.

B. Application of Mobile Agent in SCM

As mentioned in [8]-[10], there’re some advantages when mobile agent is applied in SCM: (1) Mobile agent is the delegate of tasks; (2) Mobile agent can reduce the network load; (3) Mobile agent moves autonomously and asynchronously; (4) Mobile agent facilitates parallel processing; (5) Code shipping rather than data shipping.

However, there’re some key problems that have to be considered:

1. Design pattern of the mobile agent: Because mobile agent itself has size, when it is sent out to fulfill the task, some information is encapsulated. After finishing the task, the result will be added to the mobile agent. Thus the size of mobile agent will increase. Considering the size of mobile agent, the size of information, the number of mobile agents roaming on the net, and the limitation of bandwidth, how to design the mobile agent?

2. Load balance of nodes: In the supply chain, there’s a possibility that a large number of mobile agents roaming on the net, and many agents arrive at the same node at the same time. How does the node agent provide services to the waiting agents efficiently to avoid deadlock phenomenon happening?

3. Data synchronization: The market is dynamic and changeful, when mobile agents are moving on the way to the destinations, but the information of the destinations is being changed or has been changed, how do the mobile agents sense the change in time, and how to change the moving route?

4. Routing planning: When mobile agents are assigned to complex tasks, and at the same time they need to move to lots of destination nodes, how to make a high efficient route to finish the task in short time?

5. Security problem: How to enforce the security to protect the sensitive information, and how to protect the hosts and agents from attacking?

In [7], there are eight kinds of agent design patterns: Itinerary, Star-Shaped, Branching, Master-Slave, MoProxy, Meeting, Facilitator, and Mutual Itinerary Recording. Here, we choose the branching pattern to be considered in SCM and discuss how to solve the related problems in the following section.

On the Branching pattern, the agent receives a list of agencies to visit and clones itself according to the numbers of agencies in the itinerary. Figure 2 shows this pattern.

![Figure 2. Branching pattern](image)

JADE provides Agent Mobility Service which implements intra-platform mobility. The agent mobility is simply controlled via the method doMove() in the Agent class. Java serialization is used to transmit an agent instance over a network connection by recursively recording the internal member values of the agent object into a byte stream [5].

When mobile agent needs to migrate to another platform, the Inter-Platform mobility Service (IPMS) is provided by JADE. FIPA-ACL messages are used as the transportation medium and these messages are sent between the AMSs of the endpoint platforms [5].

III. MOBILE AGENT SYSTEM FOR SCM IN FLOWER TRADING

A. System Structure

We present a mobile agent system for the case of SCM in flower trading. In the trading, the participants are buyer, seller, supplier and logistics company.

The structure of mobile agent system is designed as Figure 3. It includes four sub-agent systems and an Agency Agent System (AAS). In every sub-agent system, there’re three agent modules. For example, modules in the SellerAgent sub-system are: (1) SellerAgent indicates
the special seller, and registers its own information and services on the AMS; (2) Local information serviceAgent is a non-mobile agent module and supplies services to local agents or MAs of other sub-system; (3) Mobile agent module is responsible for managing all the MAs created by local node and maintaining the agents’ information table. Every agent module is not a single agent, but a combination of different function agents. Agency agent system works on the web server to manage all the agents’ information and all the services.

Figure 3. Structure of mobile agent system

During the flower trading processes, agents communicate or even negotiate with others as intelligent entities rather than just sending and receiving information as information reporting tools. So collaboration and interoperation among agents are the essential activities to fulfill the task. Figure 4 is the structure of an agent.

Figure 4. Structure of agent

In this system, buyers can search the flowers which are on market. When the order is confirmed, one or more MAs will be created to carry out the tasks on behalf of buyers. We choose branching as the MAs’ design pattern, and the migration type of MAs is weak migration. The basic activities of MA are: create, replicate, migrate, recall, suspend, wake, and destroy. On the Web Server, the agency agent system is configured, which contains the AMS. Every agent must register on the AMS to obtain a unique AID, and they also need to register/deregister their services on the AMS. Therefore, every registered service can be found when there’s a service requirement.

B. System Operation

There’re some function agents in this system: BuyerAgent, SellerAgent, SupplierAgent, LogisticsAgent, PurchaseAgent, QueryAgent, NegotiationAgent, OrderAgent, ManagerAgent. OrderAgents are mobile agents, which are encapsulated with different information in different process phases and for different participants. The system operation can be described as follows:

1. All the agents of sub-system register their own information and services on the AAS.
2. A buyer login the website by the browser, then choose flowers he want, and input some query conditions, such as the time limit of flowers, expected price, amount, delivery date.
3. According to the order information, BuyerAgent sends the service requirements to the AAS, the agency agent searches whether the required services exist, if there’re the right services, it will send the addresses and names of the service providers to the BuyerAgent. After obtaining the addresses of target service providers, it forms a route list for MAs, and MAs migrate to the destinations to query the matched information of flowers.
4. QueryAgent queries according to the conditions, and then transfers the query result to MAs.
5. When the buyer and the seller need to negotiate about the price, date and other information, NegotiationAgent will carry out the negotiation according to the negotiation mechanism, and then transfer the result.
to MAs.
(6) If there’re not enough amount of flowers for the order, SellerAgent will communicate with the SupplierAgent immediately to make supplement.
(7) MA moves back with the negotiation result to BuyerAgent.
(8) The buyer makes a final confirm to choose the right seller.
(9) When the trading is successful, a logistics order is generated, and MA brings this order information to the logistics company. And then the logistics company arranges the delivery.
(10) If the trading fails, both the buyer and the seller will receive the failure inform.

C. Query and Negotiation Mechanism

The flower is a special kind of goods, because flower’s lifecycle is short. When considering the query and negotiation activities, agents should obey the following mechanism:

(1) Sellers maintain their own database for all the flowers they sell. Flower’s lifecycle is one of the information items (lifecycle = leaving off market time – coming into market time). And the order contains buyer’s expected delivery date.

(2) Match according to the date: if the expected delivery date exceeds the flower’s leaving off market date, this candidate will be discarded; if the expected delivery date between the flower’s coming into market date and leaving off market date, the relative information will be transferred to MAs.

(3) Match according to the price: if the expected price is lower than all the flowers’ price, trading fails. But the flower information of lowest price will be transferred to MAs, in order to give the buyer another chance to make an order. If the expected price is between all the flowers’ lowest and highest price, flowers will be sold at the current price.

(4) The flower has discount price, for every seller, the lowest price of the flower is the discount price, and the formula is: lowest price = discount price = original price * (leaving off market time – current time) / (leaving off time– coming into market time).

Because of the special trading scenario, we need to define an ontology in order to keep agents have consistent understanding of the information. The ontology indicates the vocabulary of the symbols used in the content. Both the information sender and the receiver must ascribe the same meaning to these symbols for the communication to be effective. On JADE platform, code of ontology realizing, and code of sending and receiving information, are independent of the content language. In the Flower-trading system, we define a vocabulary named FlowerTradingVocabulary.

With the help of mobile agent system, most of the intelligent activities in SCM can be processed intelligently and automatically.

IV. CONCLUSION

In dynamic business environment, agile capability and flexibility have been the new requirements in SCM. How to improve the efficiency of intelligent activities has become the “bottleneck” and exploring point in today’s SCM. In this paper, we present a mobile agent system to make some of those intelligent activities processed intelligently and automatically. Further researches are expected to improve the agent capability with a perfect knowledge base and enforce its security to protect the sensitive information.

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