Mobile agent technology and application for online global logistic services

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Abstract

With the growing trend toward the use of international supply chain and e-commerce, logistic service providers for product warehousing, transportation and delivery are placing great emphasis on information technology (IT) to be competitive globally. Realizing that the current service tracking system merely supports order status tracking within a service provider, applies mobile agent technology for online order tracking across the global logistic alliances. Utilizes a three-tier architecture for mobile agent technology and develops a prototype system for global logistic service tracking. Demonstrates the concept and technology proposed. The online service tracking services enable customers to monitor the real-time status of their service requests and therefore becomes key tool for modern enterprises to compete successfully in a global marketplace.

1. Introduction

According to statistics from Council of Logistics Management (MOEA, 2000), 20 to 30 percent of total production costs are directly attributed to distribution and logistics management. Investment in efficient distribution and logistics management systems can considerably improve enterprise competitiveness. Further, logistics management can significantly affect the efficiency of production, distribution and the quality of total customer services.

Distribution and logistics management consists of a series of activities including warehousing, order manipulation, goods picking and dispatching, transportation and inventory control (Aitken, 1998). Since a vast amount of information is generated across the various logistic activities and participants, efficiency and quality of enterprise logistic services are hard to monitor and control. Moreover, since many participants such as freighters, distribution centers, manufacturers, and distributors are involved in the logistic service industry, a new business model is required to systematically integrate all participants. As indicated by Martin (1998), entrenched and rigid organizational structures, deep within enterprises, act as barriers to the realization of efficient logistics management. Consequently, an integrated logistics management approach will yield more profits and efficiency.

When attempting to integrate across heterogeneous organizations, enterprises typically experience difficulties in re-engineering business processes that cross boundaries. The main purpose of this paper is to provide an agent-based approach to add agility to the comprehensive logistics service tracking across organization boundaries. For instance, when large numbers of orders are transferred among different logistics service companies, the status of customer requests can hardly be obtained in real time and thus an effective approach for online status tracking of global logistic services is needed. An agent-based online logistic service tracking system (OLSTS) facilitates integration of the logistic services of different organizations without increasing Internet-based human

queries. In brief, based on the concepts of business re-engineering and information integration, this research aims at providing complex supply chain and logistic service providers with efficient and high-quality customer services by reducing the unstructured requests of traditional service tracking systems through the application of the mobile agent techniques.

2. Literature survey

This paper proposes an approach for online global logistic services using mobile agents. In this section, the literature covering online service tracking, agent-based techniques and logistics management are reviewed to formulate the research questions and basis for the approach.

2.1 Online service tracking

Along with the tremendous development in industrial engineering and management applications, including just-in-time (JIT), total quality management (TQM), supply chain management (SCM), customer relationship management (CRM), and global logistics, various computer-aided applications have been developed to assist implementation enterprises. The OLSTS is one of the more effective solutions that has been developed to support efficient customer service response. In the competitive global market, enterprises should efficiently respond to customer requests to gain market advantage. Service status tracking is the fundamental offer to provide customers a means to realize the status of their requests and to anticipate and plan actions. For a manufacturer down stream in the supply chain, this service provides real-time information that enhances the effectiveness of raw material planning and scheduling.

Since the service tracking system provides the order and delivery status of the products and services, users of the system can make decisions based on the actual status. Unlike the traditional approach, the Internet-based technique has the advantage that information exchange and transmission are not geographically restricted. Realizing the importance of efficient response (ER) to

customers, traditional, non-Internet-based approaches for business transaction and communication have gradually been replaced by Internet means (AIMO, 1999; Anton, 2000).

With the development of the Internet, numerous service tracking systems have gone online. Though users can easily access real-time status information via Web-based service tracking systems, most tracking systems cannot operate across organizational boundaries. In a highly collaborative business environment, customers need to acquire and process information from organization chain to update the service status. In light of this inefficiency, this research aims at developing a cross-enterprise, Internet-based logistic service tracking system for efficient feedback of service status.

2.2 Agent technology

Agent technology is widely used to develop flexible information systems (Van Dyke Parunak, 1998) for information collection, analysis, negotiation and conflict resolution. Web-based mobile agents are programs that act as assistants to monitor tasks running over the Internet, provide decision support, and accomplish pre-defined tasks with autonomy (Mayes, 1995). The agent can continuously perform the specified tasks over a period of time after being invoked and is stopped according to a pre-defined criteria (Graesser, 1996). An agent can be regarded as a set of computer programs with the following three attributes (Wooldridge, 1995):

(1) *Autonomy*. An agent performs most tasks without direct intervention from human or other agents.

(2) *Social capability*. Agents can interact with human or other agents to accomplish the assigned tasks.

(3) *Responsiveness*. Agents receive parameters from the environment and respond in a timely fashion to changes of circumstance.

Based on features such as mobility and functionality, agents can be classified into several types including static agents, mobile agents, information/Internet agents, collaborative agents, interface agents, learning agents, emotional agents and the multi-agent

systems. The mobile agent provides characteristics that facilitate the development of flexible and efficient Internet applications relating to multiple entities (Morreale, 1998). For business transactions involving a variety of organizations and objectives, agent technology is often employed to coordinate activities between participants so that basic requirements can be satisfied and near-optimal (or even optimal) solutions can be obtained (Nwana and Azami, 1997). In addition to coordination activities, agent technology has been used for network load reduction and fault tolerance demonstrating high stability. As indicated by Fischer *et al.* (1996), an ideal, global behavior of a complex organization can hardly be simulated. Thus, through the use of agent technology, business uncertainty can be significantly reduced (Rothermel *et al.*, 1997). Furthermore, by using the agent technology, application systems can establish intelligent agents to interact with other agents of remote hosts on the basis of predefined restrictions and objectives (Falchuk and Ahmed, 1997).

Agent technology can be used to provide critical information for product services, product reformation and recycling (PPP, 1998), and further development shows promise for applications for logistic service tracking of a product in the supply chain (Watson and Pitt, 1989; Chandra and Kumar, 2001; Lummus *et al.*, 2001).

2.3 Logistics management

The distribution center is the hub and channel location that provides storage and transportation support to consumers, enterprises and other logistic service providers. Distribution services and logistics management are the core issues for successful operations of distribution center (Huang *et al.*, 2001). Logistic service companies, such as UPS and FedEx, provide enterprises and individuals with systematic transportation management, demand forecasting, information management, warehousing, inventory control and distribution services (www.acq.osd.mil/dp/dars/ dfars/html/ r20020129/247_3.htm). The distribution center is an organization that aggregates and distributes goods for customers. In a highly specialized global logistics environment, the key players are the manufacturers, warehousing

service providers, domestic freighters and international freighters (Trappey and Hou, 2001). In addition, wholesalers and distributors combine their roles to sell and deliver goods from multiple manufacturers to international clients through a centralized channel. Through various distribution channels, the global logistic services facilitate goods delivery between various enterprises that are geographically separated. Furthermore, goods delivered from the supplier side to the customer side rely on information management of the goods transportation and warehousing so that efficient and systematic enterprise operation can be ensured. Therefore, an applicable service tracking approach integrating diversified logistic service providers is required. An agent-based model is presented in this paper to provide online logistic service tracking. The system analysis and design is explained in Section 3. In Section 4, a prototype system and a case scenario are introduced to demonstrate the approach.

3. OLSTS design and analysis

In this section, the business analysis, architecture and functions of the proposed logistic service tracking system are discussed. The objectives of the proposed approach are to provide customers with an intelligent mechanism to track the service status among inter-organizational, global logistic alliances. The system is designed for the following three participants to meet their operational requirements and to enhance their business competitiveness:

(1) *Customers.* Expect their requests for products or services from distributors and manufacturers to be fulfilled on time.

(2) *Product/service suppliers.* Receive the orders from customers and efficiently fulfill them by cooperating with the logistic service providers.

(3) *Logistic service providers.* Provide logistic services with a full range of information support provided to both buyers and sellers in order to enhance the business efficiency of the customers.

3.1 Coordination model analysis

In general, a procurement process within a supply chain can be depicted as shown in Figure 1 At first, a consumer places an order to the retailer and then the retailer may request the logistic service provider to deliver goods to the consumer. If the goods to be delivered are out of stock, the retailer replenishes the goods from the manufacturer. When the retailer receives the goods from the logistic service provider, the goods are then delivered to the consumer.

As noted above, the merchandise transportation among the participants in the supply chain relies on the logistic service providers. The logistic service providers play an essential role in distributing and delivering merchandise to the consumers, the retailers, the

Figure 1 Interactions between members of the supply chain
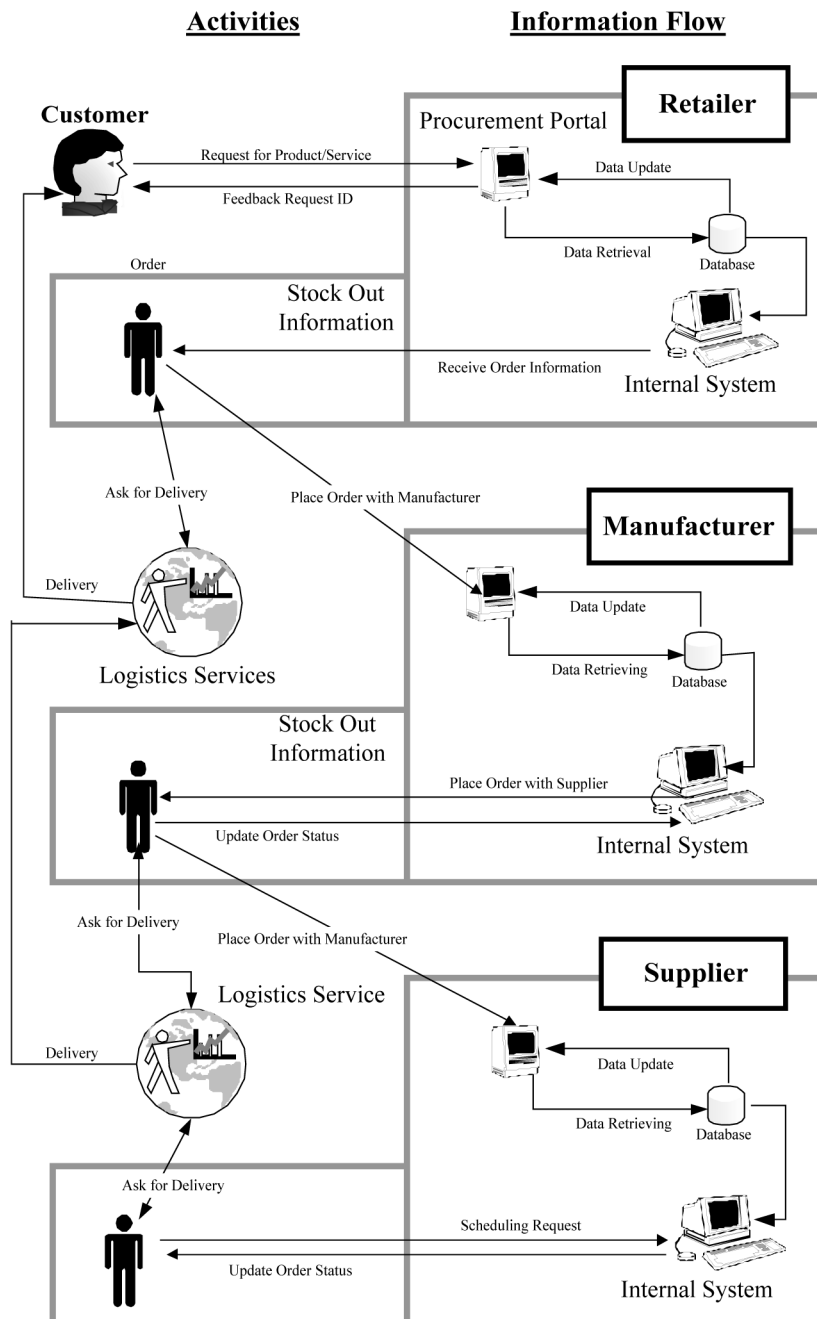
manufacturers, and the raw material suppliers. Delivery of products from suppliers to foreign customers may be accomplished by intermediary distribution centers and logistic overseas service providers. Therefore, real-time interaction and coordination among logistic service providers, distribution centers, suppliers and customers are necessary for ERs to customer requests (Figure 2).

3.2 Agent architecture

As shown in Figure 3, the OLSTS modifies the previous three-tier architecture of the software agent (Adam *et al.*, 2001). Unlike the other applications, agent technology provides higher flexibility, mobility and intelligence to the entire system. Table I summarizes the way agents interact with system users and external

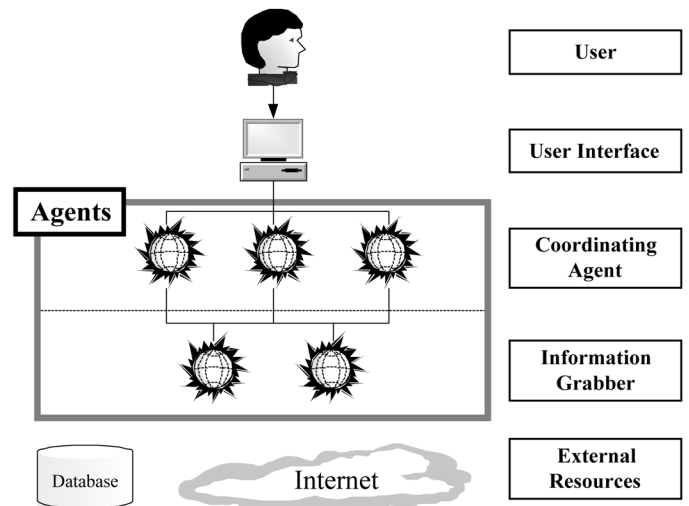**Figure 3** Three-tier architecture for the agent application

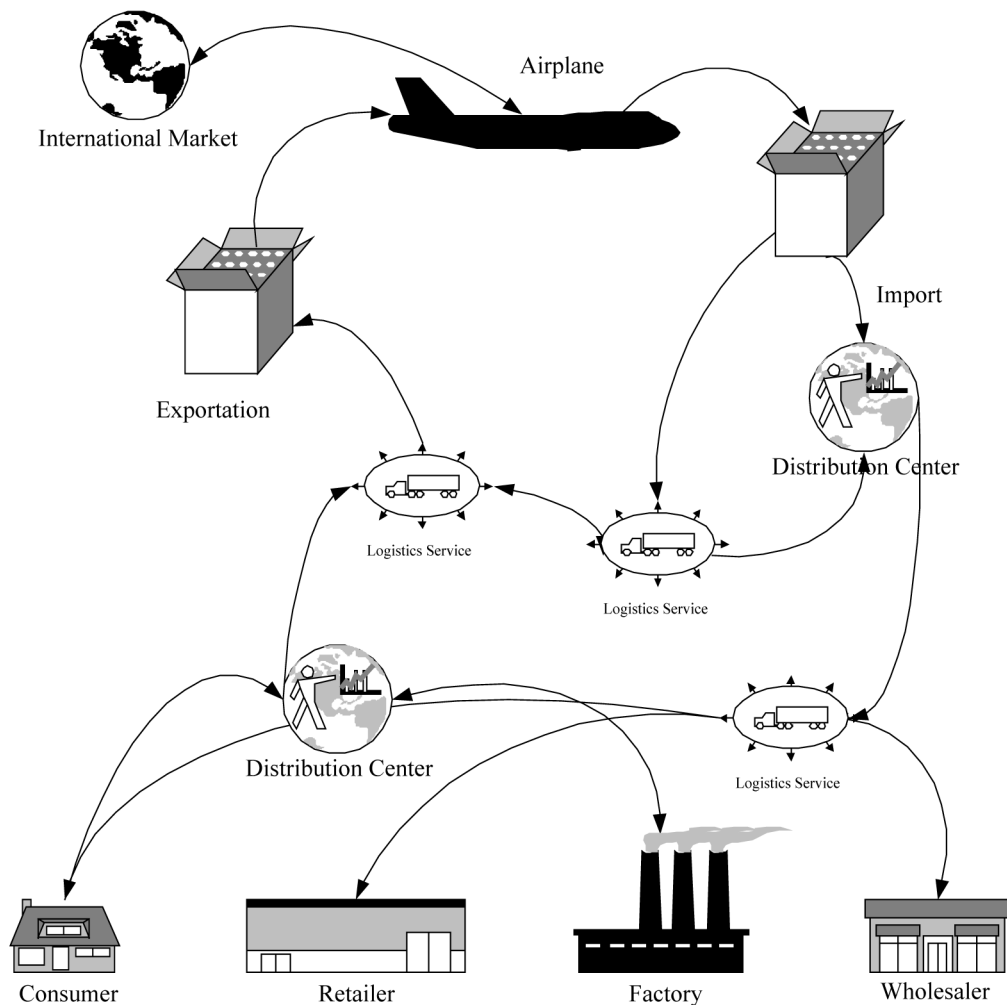**Figure 2** Illustration of global logistic services

Table I Summary of interaction between different components of the agent system

Component	Roles
User	A user sends a request to the agent system
User interface	Interface for information acquisition from the user and information passing to the coordinating agents
Coordinating agents	Coordinating agent obtains the information from the user and then performs coordination between agents to fulfill user's request
Information grabber	After coordination, the coordinator passes the information to information grabbers. Information grabbers collect related data from external resources
External resources	External resources are where the required data are located

resources as well as the way they cooperate with each other.

As shown in Figure 3, an agent-based logistic service support system consists of three key segments, including the agent center as the service tracking kernel, the supply chain coordination channel, and the global logistic service operations. To seamlessly integrate the global logistic services, SCM and logistic information, an agent-based OLSTS is developed. The architecture simplifies the complexity in tracking logistic service status as a great number of requests are simultaneously handled in the various enterprises of a supply chain. In our design, the tracking process is triggered by the logistic service tracking request from customers. As the process is activated, the agent-based system dispatches the agents to track the service status in the logistic service alliance to locate the specified request. A local agent is then created to collect the related information about the customer request from the database of the specified location. Using this mechanism, the security risk of directly authorizing outside agents (other than local ones) to access the database can be avoided.

In the latest OLSTS, the service status can only be tracked within one corporation. That is, if the logistic service request involves several participants or logistic service providers in a supply chain, the service status of the specified request cannot be readily tracked via the traditional approach.

3.3 System design
As stated in previous section, the process of logistic service status tracking is summarized as follows:

(1) The client fills out a form to request the agent system of service status tracking via a portal Web site.
(2) The service status is display on the Web page.
(3) The user accesses the specific hyperlink to obtain detailed information provided by the logistic service provider where the request is currently served (see Figure 4).

Figure 5 depicts the overall status tracking processes from the user's perspective and the result of tracking is displayed in a format containing request ID, request title, request date, location and company serving the request. In addition, a hyperlink is provided for each request so that a geographic graph can be displayed for visual illustration of the current location of the request.

This proposed architecture can be further divided into tracks for the dealer side and the data side. The agents on the dealer side are responsible for coordinating the entire agent system while the agents on the data side are responsible for the data collection from local database. Four modules are included on the dealer side:

(1) *Receiver.* When the user fills out the service tracking form via the Web-browser, a receiver receives the request from the client side and triggers the tracking activities.
(2) *Agent assignment and dispatching.* An agent center is established on the dealer side and the IPs and related information of the destinations (i.e. the alliance members such as the logistic service providers) are specified in the central database. In this module, the coordinating agents are dispatched to the destinations based on the

Figure 4 The conceptual framework for an agent-based logistic service service support system
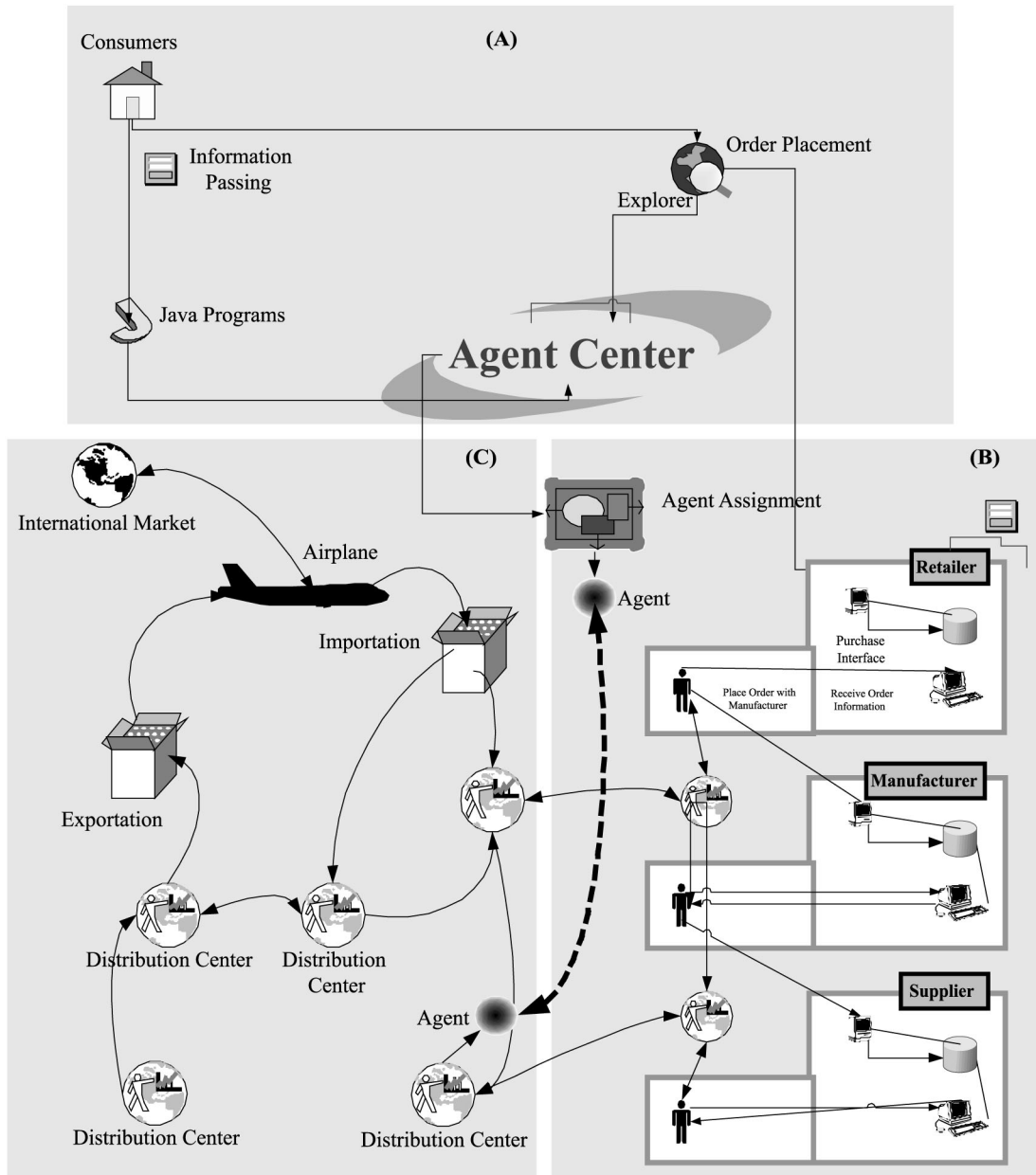
information acquired from the central database (Figure 6).

(3) *Coordinating agent.* The coordinating agent is dispatched to each alliance member under the agent platform and interacts with the information collector.

(4) *Presenter.* The text and visual displays of tracking the service status are generated by this module.

The data side consists of the following three modules

(1) *Coordinating agent.* Acts as the coordinating agent on the dealer side (the agent center). The agent is dispatched to the destination, and the authority of the coordinating agent is validated by the agent system at the data side (destination). After authorization, the coordinating agent on the data side is invoked to interact with the agent from the dealer side.

(2) *Information collector (grabber).* After receiving the request from the coordinating

Figure 5 Process for status tracking from the user's perspective

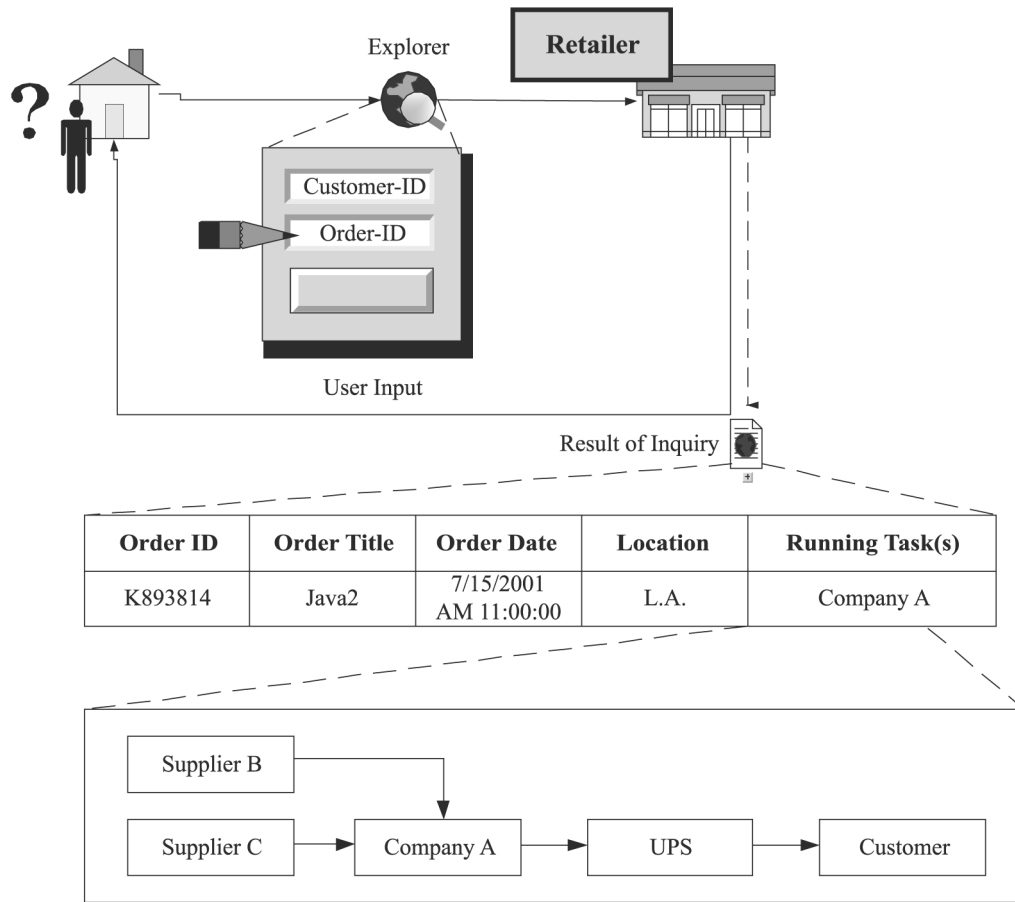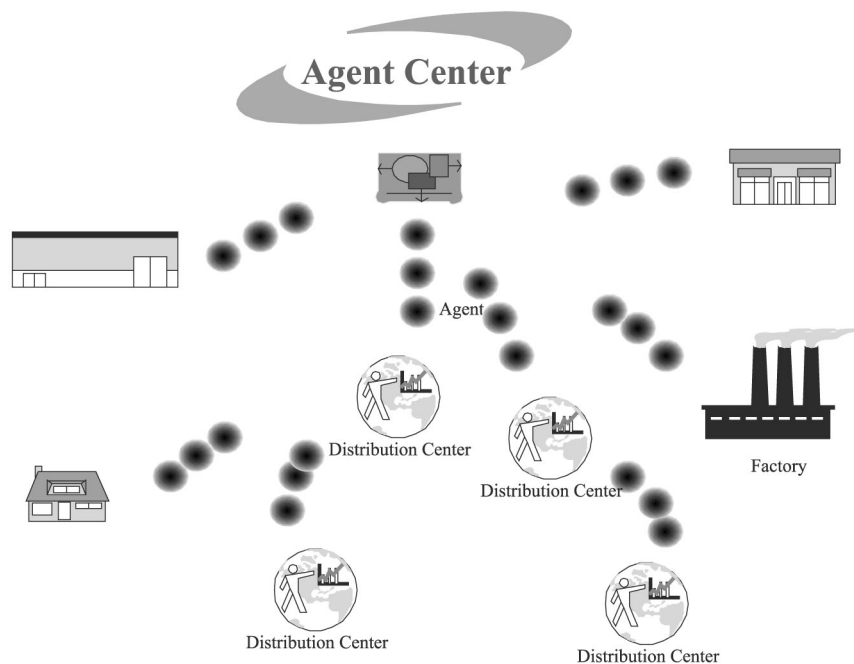| Order ID	Order Title	Order Date	Location	Running Task(s)
K893814	Java2	7/15/2001 AM 11:00:00	L.A.	Company A

Figure 6 Illustration of agent dispatching

agent, the information collector captures data from the external resources to check if the specified service request has been handled on site. Since the database access request is separated from the accessing authority, database security is improved (Florescu *et al.*, 1998).

(3) *Presenter.* The presenter on the data side provides more information to the dealer agent (or the customer). Through this mechanism, the alliance members can maintain information presented to the customers using their local agent platform.

4. System implementation and case study

A prototype implementation of the system architecture and design described in the previous section is discussed in this section. In order to illustrate the effectiveness of the prototype system, a global logistic service scenario is provided for the demonstration.

4.1 System functionality

From a technical viewpoint, the service tracking process from the request to the feedback of the agent system is illustrated by Figure 7. The system documents three types of participants including the user, product/service vender, and the logistic service provider and automatically identifies the role of the user via the customer ID. Through the use of the proposed system, the logistic service provider can track the distribution status while the vendor can provide customers with efficient and accurate service status feedback. As depicted in Figure 7, interaction between the user, agent center and supply chain sectors consists of ten steps:

(1) *The customer sends the customer ID and service request to the vendor via a portal page.* The portal page of each client (i.e., the product/service vendor) can be established on any type of Web server. To ensure confidentiality, the customer ID is validated before the tracking process is activated. In the prototype system, six tracking indices, including the order ID, vendor, title, ordering date, expiration date and running task, are provided for tracking the requests (Figure 8). That is, the

customer can track the status of previous service requests using the six indices. This feature enables the customer to track the service request with more options for keyword specification. Details of the six indices are explained as follows:

- *Order ID.* Each service request is specified a unique ID by the service provider.
- *Vendor.* The vendor that is selected to satisfy the customer's request for product or service.
- *Title.* The descriptions of the requested product or service.
- *Order date.* The date that the customer requests for products or services.
- *Expire date.* The expiration date that the requested products or services should be provided.
- *Running task.* The company that currently serves the customer request.

(2) *Pass the input information to the agent center.* The portal page at the client-side has two features to interact with the agent center. First, the format of the input information at each side complies with that of the agent center. Second, the corresponding agent center manipulates the pre-defined input information (e.g. IP) so that the user request can be correctly passed to the agent center.

(3) *The agent center receives the input message.* In the agent center, a critical component called the agent Web server checks and responds to the customer requests. The agent Web server plays an essential role in initiating the operation of the OLSTS. At this step, the agent Web server collects the customer tracking request from the Web server on the client side. A sequence of activities are then activated by the agent Web server based on the request. A confirmation page is generated by the agent Web server after the request is fulfilled.

(4) *The agent hub determines the destinations for agent dispatching.* The AgentCenterHub agent is invoked by the agent Web server as the means by which the coordinating agents work is determined. Under such circumstances, the AgentCenterHub agent retrieves the addresses of the alliance

Figure 7 A technical view of the service-tracking process
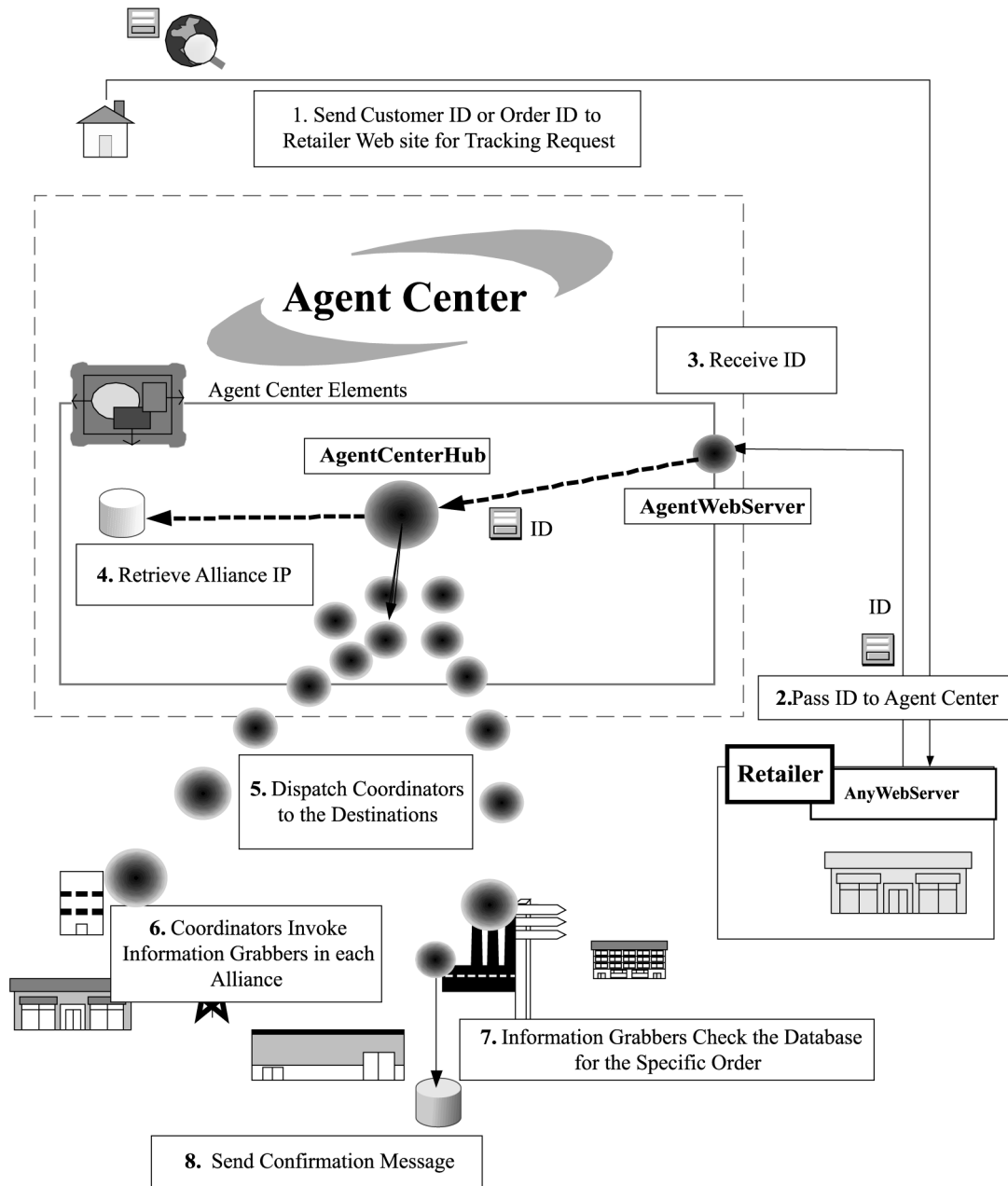
members from the database of the agent center. The procedure is regarded as the locating mechanism. The addresses related to the previous stages of the tracking request are omitted in the locating mechanism. Thus, if the route of a logistic service is given before the agent is dispatched, the coordinating agents can be dispatched to locations that the service might be currently handling. Using this approach, network traffic loading can be reduced and efficient status tracking can be ensured.

(5) *Dispatch agents to the destinations.* After the AgentCenterHub agent determines and retrieves the addresses of destinations, the coordinating agents are then invoked and transmitted to destinations with the tracking request information.

(6) *The coordinating agent invokes the information grabbers.* As each coordinator arrives at the specified destination,

Figure 8 Prototype interface for tracking order status

authority of the coordinator will be checked by the local agent system at the destination. After authorization, the local system will invoke the coordination program stored on the data side. Meanwhile, the information collector is activated and the tracking information is passed from the coordinators (i.e. the dealer side and the data side) to the information collector. That is, prior to the coordinator being dispatched to a remote host (i.e. the destination), the coordinator is placed under the control of the agent center on the dealer side. On the other hand, when the coordinator arrives at each destination, the coordinator is controlled by the agent system on the data side. Therefore, coordinating agents with identical format and structure are required on both the dealer and the data sides. Otherwise, the coordinator will be rejected when moving from the dealer side to the data side. Moreover, since the coordinator from the dealer side is controlled by the application at the data side, data security on the data side can be guaranteed.

(7) *The information collector checks the request status in data side.* If the coordinator from the dealer side is approved, the coordinator on the data side will then invoke the information collector. On each data side, an information collector is established to check the request status from the database on the data side. Under the structure,

heterogeneous database systems can be used on the data side since the information collector is simply controlled by the agent system to retrieve the status information from the local database. The status information that can be retrieved from the database includes:

- ORDER_ID: Each logistic service request has a unique ORDER_ID for identification.
- ORDER_TITLE: The descriptions of the product or service for distribution.
- ORDER_DATE: The date that the logistic service was requested.
- RUNNING_TASK: The company that currently serves the logistic service request.
- ARRIVAL: The arrival date of the logistic service request to the company.
- STATUS: Status of the logistic service request in the local system.
- TASK_HTTP: The local system can provide more information for tracking the request via a hyperlink.
- CUST_ID: ID of the customer that requests logistic service tracking.
- COM_NAME: The headquarter of the company serving the request.
- FROM_: The company that the service request is from.
- TO_: The next company that the service request will be passed to.
- TIME_2_SPARE: The remaining time for the service request to be finished in the current server.

Using this system, the status is categorized into three types including "IN", "OUT" and "ONWAY" where "IN" and "OUT" denote whether the request is served in this company or not. In addition, owing to network traffic jams, some service requests might be simultaneously manipulated in different companies. To avoid data redundancy, the "ONWAY" status is used to indicate the suspending condition that the service request is on the way to the next server. The agent system will check the status in the destination if the local status is "ONWAY". If the destination status is "IN", the destination will be regarded as the current server. Otherwise, the local

company that dispatches this logistic service request is considered as the present server.

(8) *Confirmation among coordinators.* If the service request is validated to be served by a particular company, the corresponding information collector will respond to the coordinator and pass the tracking result back to the agent center on the dealer side. As each information collector finishes status checking and passes the result to the

dealer side, the agent center stores the results in a temporary repository. The format of this repository table is identical to the status table on the data side and a collection of status information from different destinations is established.

(9) *Display the tracking results.* Following agent coordination and information collection, the tracking results can be displayed on the user Web page generated by the agent Web

Figure 9 Roles of the components in the agent system
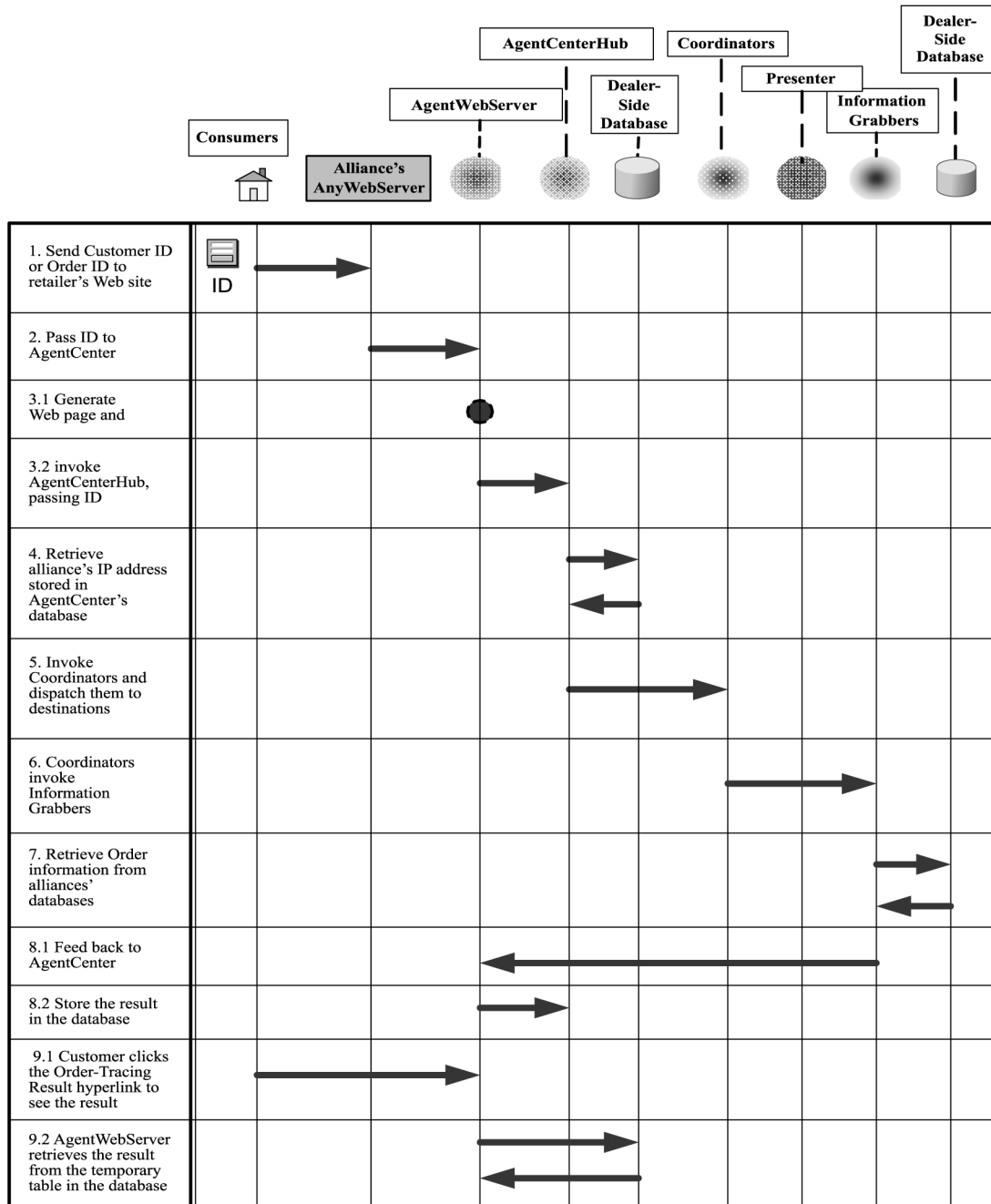
server. The agent Web server retrieves the collected status result from the temporary repository and sends the result to the user via the Web page.

(10) *Display the detailed information about the request.* The company that currently handles the logistic service will be activated as the customer sends the tracking request, and the detailed service information will be retrieved. In order to provide coherent visual information to the user, a geographical display of the logistic service status is incorporated into the prototype system. The graphic representation provides information about the geographical relationships and sequences between the logistic service providers. In summary, the roles of the components in agent systems (on the data and dealer sides) can be mapped to the steps shown in Figure 9.

4.2 Case study

In this section, a logistics service alliance provides an operation scenario to illustrate the system functionality. In the scenario, two alternative routes are designated to distribute the cargo. For high-valued, specialized cargo, airfreight is usually the first choice for service. However, the corresponding service fee is higher. For cargo that have greater bulk and are not constrained by time, ocean shipping is usually selected in order to reduce transportation costs. There is a large volume of merchandise distributed via the logistic service alliance with the A company having three branches and the B company having an airfreight center as shown in Figure 10. A total

Figure 10 Illustration of the demonstration scenario

of three cases concerning different roles in the alliance are discussed as follows:

(1) *The consumer provides the information for the tracking request via the Web portal.* A customer with ID 893814 request a particular vender (whose logistic service provider is A Co.) to provide raw materials for production. Several days after the request, the customer checks the status of his request. The customer connects to the A company. Web portal and follows several procedures to track the product request.

Initially, the customer keys in the customer ID, password and keyword to specify the service request to be tracked. After the user clicks on the "order-tracing result" hyperlink, the status tracking result is displayed. As shown in the textual tracking report in Table II, two of the customer service requests are provided by the logistic service providers. The user can click on the hyperlink related to each service request for detailed service information (in this case, the request titled "HTML" is selected). This request is handled by a branch of A Co. in South Africa. As indicated in the geographical illustration, the goods distribution is achieved by a branch of A Co. in Europe and then delivered to the branch of B Co. in Singapore.

(2) *The logistic service provider tracks the distribution status.* If a manager in the A Co. headquarter would like to determine the current distribution service status of A, then the account number is entered under the request tracking system. As shown in Table III, a summary of the current status for the distribution services across all A Co. branches is displayed. Based on this information, the manager can derive strategies or make decisions. For instance, too many requests might be held in the branch in South Africa and more transportation capacity might be required at this branch.

(3) *The product vendor tracks distribution status of the requested product.* TSM is one of the key product manufacturers in the alliance. In order to ensure that all the requested products for TSM are distributed within the time scheduled, a TSM manager uses
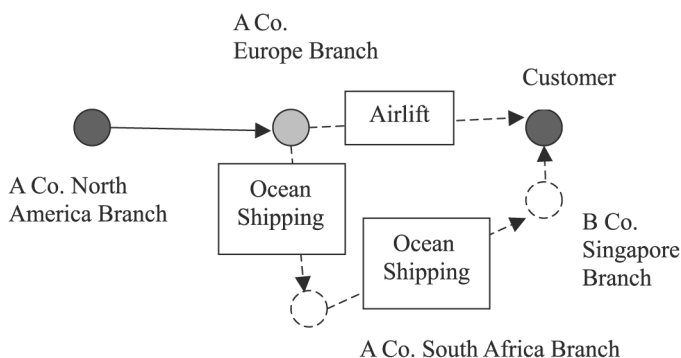
Table II Report of the tracking request

Customer ID	Order ID	Order title	Order date	Vendor	Running task	Arrival date	Time to spare (days)
893814	00003	IC_00793	2000/1/1	TSM	FeDesSingapore	2000/1/3	0.5
893814	00010	HTML	2002/1/4	B-book	UPXSouthAfrica	2002/1/5	0.5

Table III Summary of A's distribution status

Customer ID	Order ID	Order title	Order date	Vendor	Running task	Arrival date	Time to spare (days)
893813	00011	CK_T-shirt	2002/1/1	CK_T-A1032	UPXSouthAfrica	2002/1/3	1
893814	00010	HTML	2002/1/4	B-book	UPXSouthAfrica	2002/1/5	0.5
893817	00585	NIKE_T21	2002/1/1	NIKE_A2201	UPXSouthAfrica	2002/1/2	1.5
893819	IK221	Solaris_A44	2002/1/2	SU	UPXEurope	2002/1/4	6
COM2B	09343	NIKE_Dry-Fit	2002/1/3	NIKE_A2201	UPXSouthAfrica	2002/1/4	1
COM2B	KID332	IC_AA21	2002/1/3	TSM	UPXSouthAfrica	2002/1/5	1
COM2B	KID336	IC_D21	2002/1/3	TSM	UPXSouthAfrica	2002/1/5	1
COM2B	00002	Windows	2002/1/1	MS	UPXNorthAmerica	2002/1/3	5
COM2B	DDF22	WD-40	2002/1/1	TSM	UPXNorthAmerica	2002/1/3	3

Table IV Distribution status of the requested products of TSM

Customer ID	Order ID	Order title	Order date	Vendor	Running task	Arrival date	Time to spare (days)
COM2B	KID336	IC_D21	2002/1/3	TSM	UPXSouthAfrica	2002/1/5	1
COM2B	H7628	IC_KK89	2002/1/2	TSM	UPXEurope	2002/1/4	4
COM2B	KID332	IC_AA21	2002/1/3	TSM	UPXSouthAfrica	2002/1/5	1
COM2B	DDF22	WD-40	2002/1/1	TSM	UPXNorthAmerica	2002/1/3	3
COM2C	DAA	IC-4422	2002/1/1	TSM	UPXNorthAmerica	2002/1/5	2
COM2C	FFF35	IC-4422	2002/1/2	TSM	UPXNorthAmerica	2002/1/4	4
COM2C	FD115	IC_4456	2002/1/3	TSM	UPXNorthAmerica	2002/1/5	3
COM2D	FF111	IC_4411	2002/1/2	TSM	UPXNorthAmerica	2002/1/3	3

the system to track the status of all customer requests. As shown in Table IV, the manager can systematically evaluate the service quality of the logistic service providers in the alliance.

5. Conclusions

This research proposes an agent-based OLSTS to improve business operation efficiency through information collection. The architecture of the agent-based OLSTS consists of agents at the dealer and data sides to ensure data security. With the application of agent technology, the information at different locations worldwide can be efficiently and accurately collected. A demonstration case is provided to explain the functionality of the prototype system. The proposed system systematically integrates organizations in a supply chain or an alliance (including the product/service provider, logistic service provider and common customer) so that all the participants can use the system to trace the product distribution status and to evaluate the logistic service capacity and service quality of the logistics companies.

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