An Agent-Based Approach for Integrating Logistics Services into a B2B Marketplace

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ABSTRACT

In e-commerce, Business-to-Business (B2B) interactions, like e.g., electronic negotiations and auctions between suppliers and customers, could be significantly improved by enabling their participants to adapt their negotiation and bidding strategies to current logistics information (e.g., about estimated transportation cost) while the interaction goes on. In this paper, we present an agent-based information and trading network enabling companies to optimize their B2B interaction strategies by integrating current logistics information into their business processes. We realize this by a multiagent-based auction site offering integrated logistics services that can be requested during an auction by sellers and buyers for getting information about actual logistics information, e.g. about transportation conditions (including cost, date, etc.). The integrated, agent-based logistics services provide the auction site users with the capability to check on the status of their orders, logistics processes, and their current delivery schedule at any time, also by using mobile devices like WAP phones.

Keywords: e-commerce, logistics, planning & scheduling, multiagent systems, auction, co-ordination, multiagent system architecture, I-commerce

1. INTRODUCTION

E-commerce has the capacity to change the way the entire world does business, because it enables people to buy and sell goods and services from anywhere in the world. Especially in business-to-business markets their is a great demand to announce offers and information about goods to a large audience and in quicken the negotiation before perishable goods get a loss in quality. Also just-in-time production and procurement is an very important issue the companies have to face. Thereby the ability to access and send information anywhere - at any time - is helping to improve the flow of information. Taking the advantage of these new opportunities enables an optimisation of the business processes of the participants.

Not only the flow of information can be improved, but also the co-ordination process and the scheduling of tasks while fulfilling a contract. Going a step further logistics services can support the buyer also before he has bought some goods and has to transport them. These services can help the buyer while he is in a negotiation phase. Before the buyer gets in contact with a supplier or seller, he has to evaluate his needs and the amount of money he is able to spend for purchasing the desired goods. When the negotiation begins the buyer normally has only a vague idea of the total costs including the amount of money to purchase the good plus the cost for the transportation and storage of the goods in different locations. Hence a trading and negotiation platform like a market place should provide services for logistics, which offer the participants the possibility to send hypothetical requests for transportation and storage to logistics companies. Hereby the requests are non-committal, because during a negotiation the buyer cannot be sure that the actual negotiation partner is the partner with whom he will make a contract. Especially when the buyer wants to purchase goods by an auction, it is totally unclear if he will get the desired good from a chosen auction. Therefore the logistics companies have to use a modified planning mechanism to answer binding requests as well as hypothetical inquires.

In this paper we present an agent-based approach for integration of logistics services into e-business negation processes and show how the interaction between the participants can be accomplished. We then briefly describe main problems that occur during planning and scheduling while extending a negotiation platform with logistics services and finally propose a solution to overcome these problems.

2. AN INFORMATION AND TRADING NETWORK APPROACH

To follow up the demands for the integration of logistic services in e-business solutions a project, called CASA, was founded by the German Research Centre for Artificial Intelligence (DFKI). The intention of the project CASA (Co-operative Agents and Integrated Services for Logistic and Electronic Trading in Forestry and Agriculture) is to establish mobile, integrated services in selected application scenarios within the domains of forestry and agriculture in the local county. Hereby agent-mediated services support the main operative business processes users are performing in each of the following application scenarios: (1) customer-oriented, dynamic timber production, (2) trading of timber via different types of auctions, fixed or negotiable price by using mobile devices, and (3) electronic trading of cereals.

The paradigm behind the ideas of the CASA project is to establish an information and trading network (ITN) for *integrated commerce* (i-commerce), which can be seen as an operational extension of traditional e-commerce [7]. The basic ideas of i-commerce are (a) to get customers more involved in the activities related to his orders or tasks to be jointly accomplished by one or multiple contractors, and (b) to get related processes in the considered supply chain more integrated in practice. Due to this, a lot of uncertainties in information and in the correct execution of delegated tasks exist and have to be handled immediately when they occur.

The main objective of the CASA project is to offer services, which leads to a better and more effective integration of production, logistics and trading processes. Therefore the CASA project designs, implements, and evaluates an innovative system for electronic commerce. The system is built to integrate significant future trends and make them useable for users of the information and trading network. These trends are:

- Integrated electronic commerce (I-Commerce) - an extension of e-commerce by special information services which could be used during trading processes.
- The use of mobile end devices in e-commerce processes (M-Commerce)
- Intelligent software agents

The ITN offers its users new integrated services for negotiation, communication and exchange of information, which enable them to work closer together. As a consequence, a refinement can be achieved by an integration of logistics services during planning and negotiation phases. To improve the accessibility, functions and services of the ITN are usable by a computer connected to the Internet or by mobile end devices like WAP phones.

2.1 Holonic Agents structure

We differentiate between following groups of participants in the ITN: producers/sellers, buyers, and logistics companies. Each member of these groups is represented in the ITN by an appropriate kind of software agent, a so-called *holonic agent* [5]. This concept of holonic agents [3,4] is used for reasons of effectively accomplishing complex, mostly hierarchically decomposed tasks and resource allocations in the selected application scenarios. A holonic agent (or holon) co-ordinates and controls the activities and information flow of its subagents. In a holonic multiagent system, autonomous agents may join others to form, reconfigure, or leave a holon.

According to this technique of holonic agents, there exist personal assistants representing human users in the ITN. This agent pro-actively acts on behalf of its user even if he is off-line. It is the coordinating head of a set of other specialized agents for individual negotiation, participation in auctions, finding other relevant partners and information, and elaboration of best trading strategies over time.

Each of these corporations is represented by a special holonic agent system according to its task-oriented subdivision into departments for information management, logistics, and production planning. In this context we presume that

- *Information management* services provide information either on certain products and related production processes, or on current market situation and potential competitors.
- *Logistics* services support the co-ordination of machines for production and transport, human resources, and storage capacities.
- *Production planning* services support short-, middle-, and long-term product planning cycles.

A so-called corporation holon is constituted by other holonic agents each of them representing a special department and corresponding complex tasks and services. Since in the ITN the roles of buyer/retailer and seller/producer may be interchangeably used, both are modelled by similar holonic agent structures. We distinguish between buyers with logistics departments and such without. In addition, logistics companies are usually contracted by other corporations for the purpose of time- and cost-saving delivery of goods on demand.

Finally, we have developed agent-based services for a distributed virtual market place to enable different kinds of trading between the participants of the ITN such as multiple online auctions and sales via fixed or negotiable prices in bilateral negotiations at the same time. Each registered user of the ITN may, for example, initiate and perform one or multiple, different auctions of its own goods and products at any time, anywhere.

2.2 Agent-Based Services

In general, the agent society provides the following classes of services to its users and is coordinating the effective execution of each of the services.

- *Auction mechanisms* including Dutch, English, Vickrey, and First-Price-Sealed-Bid auctions.
- *Integrated services for dynamic pricing*. Agents collect additional information on transportation costs and other constraints to meet as a decision-support service for its users, for example, during the bidding process of running auctions.
- *Logistics services* provide dynamic, approximately optimal (re-) scheduling and (re-) planning of transportation; we use an extended version of the contract net protocol with simulated trading [1,2] for the purpose of optimal transportation planning and scheduling.
- *Information management.* Agents gather relevant information on behalf of its users in different trading and production settings.
- *Mobile services* to let the users access most services of the ITN also on WAP-enabled mobile devices.

3. THE APPLICATION SCENARIO

These services of the CASA ITN have been build with a special focus on supply-chain activities in the forestry domain, in which a lot of dynamics occur during the production, the negotiation and the transportation process. Regarding these dynamics an adaptive system has to be built to fix the plans of the participants just-in-time, when a problem occurs.

In this scenario, we concentrate on that point in a supply chain, of which the production is finished and the negotiation for the sales begins. The basic component of the ITN is a market place that provides services for direct price negotiation between a seller and a buyer, but also offers services for initiating and performing auctions of various types like English- , Dutch- , Vickrey- and First-Price-Sealed-Bid auctions. To enhance the usability and flexibility of the ITN, these services are built upon autonomous agents. The main benefits of the agent-based service support are the concurrent execution of delegated tasks like acting in an auction in accordance with the user's preferences or in finding partners for a given problem. Hereby an agent can be sent out to find special logistics services e.g. for a transportation task or a company offering particular machines and know-how to solve a given problem.

Especially the logistics services are useful while participating in a fast progressing auction such that the bidder does by himself. In this case he needs assistance to find a shipping company that can do the job in a predefined time span at approximately lowest cost. But these new services need a counterpart in the organization of logistics companies, which allow fast re-planning, dealing with hypothetical requests and a flexible resource management.

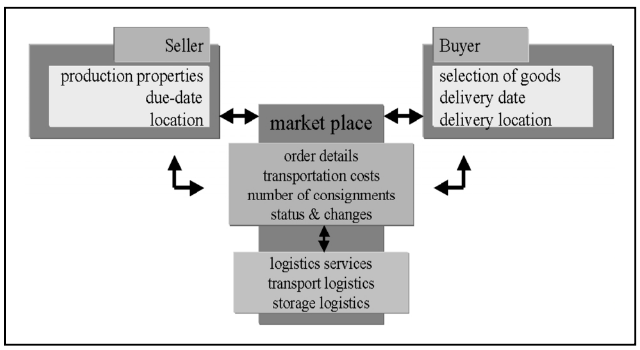

Figure1. Relationships between the members of the CASA ITN.

Figure 1 shows the coherence between seller, buyer and (mediated by the market place services) logistics. During a negotiation phase seller and buyer bargain about the conditions of a contract and its fulfillment. They have to clarify the amount of goods to transport, when and where to start and end the delivery at a given destination and the spreading of the goods to single transportation tasks. This information builds the basis for a request to a logistics company, which in turn is then able to compute an answer containing detailed information about the transportation cost, time span and used resources. The planning and scheduling within a logistics company is a very complex task, on which we concentrate in a following section of this paper.

Hence, the ITN offers all its users the possibility to invoke such integrated services for decision-support during the participation in one or multiple different auctions. For example, a personal agent may concurrently determine the optimal transportation cost and delivery dates of some auction good for each individual bid of its user. As a result, the agent may notify its user in real-time if estimated optimal transport costs exceed the allowed limit due to given buying preferences or if some deadlines are at risk to be exceeded.

3.1 Interaction among the CASA ITN

The integrated trading services are provided by holonic-structured agents, which support the interaction between the different types of participants in this scenario, namely seller and/or auctioneer, buyer, and logistics company. Figure 2 summarizes such interaction in case of an mobile timber auction. First a seller initiates an auction on a trusted auction site and informs potential buyers about offered goods, the auction type, and related bidding policy. During an auction bidders may evaluate their bids, monitor the current auction process, and place bids according to their individual bidding strategy. Latter may evolve depending on the result of the integrated services and respective benefits for the individual bidder. In addition, each of the information and trading services is available for registered users of the ITN on mobile WAP enabled devices such as smart phones or PDAs connected to the Internet via modem. Appropriate agents perform the necessary

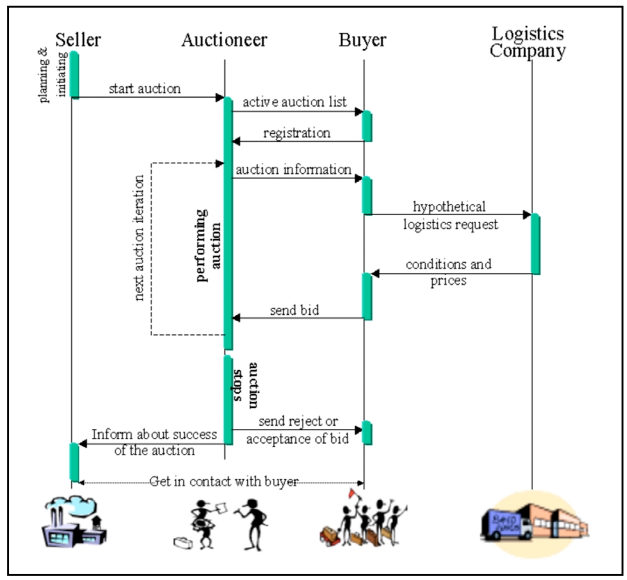

Figure 2. Interaction between participants in a mobile timber auction.

synchronization of mobile and PC-based home computing equipment, which is connected via the ITN. Participation in any trading process can be delegated by the user to its personal agent which then is in charge of negotiating or bidding at an auction, and notifying its user when needed, e.g., via SMS or email.

3.2 Agent Society of the CASA ITN

Due to the uncertainties in the execution (e.g. traffic, machine failure, etc.) and of the hypothetical requests the system has to be flexible in doing fast re-planning and reorganizing. We apply a holonic structured multiagent system as they are well suited for dealing with complex tasks (e.g. planning tasks) that can be divided into a set subtasks. Holonic MAS exhibit the features of stability and robustness since one agent can often take the role of another agent in case the latter agent is inhibited or suspended for some reason. Furthermore, agents in MAS are characterized by their capability of exchanging messages to achieve co-ordination and co-operation.

The four groups of participants in the ITN will be represented by complex agent structures, which consists of holonic agents (see figure 3): Sellers, buyers, logistics and public market places build the elements of the ITN. The group of participants who want to sell their goods are represented by four holonic agents, which characterize the departments of the company involved with the trading process. There is a holon for representing the planning department of a company. A second holon has to cope with the information needed for the offering. It administrates not only information for the current offer, it also holds information about the own production, storage capacities and if available, information about the market situation. This information builds the basis for the plan generation, internal pricing and choice of a selling strategy. The third holonic agent represents the company as a whole to the ITN and is the contact for direct negotiation with another company. The last holon represents the user in the agent network. It behaves like it is described before to support the user during his work and interaction with the system.

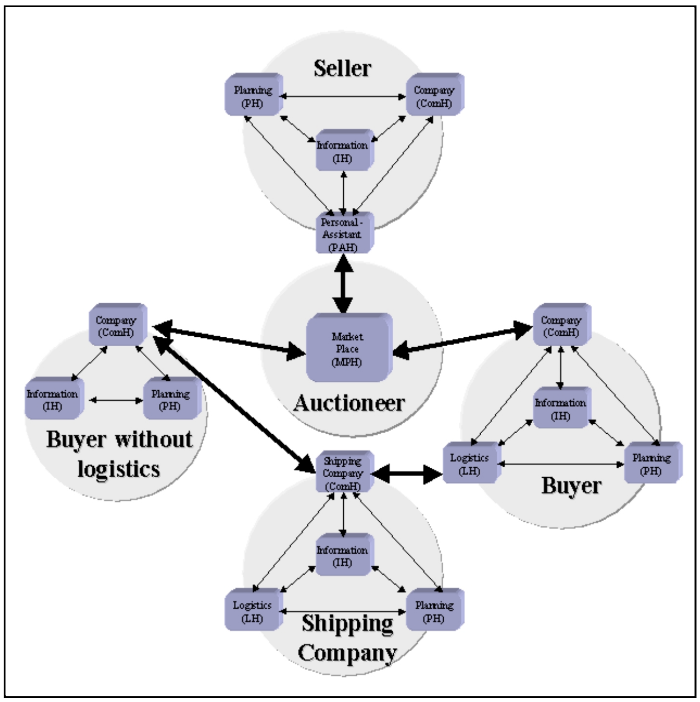

Figure 3. Holonic agent structure in the application scenario.

The holonic agent structure of the buyer is of a similar design as the seller is represented. We distinguish between buyers with logistics departments and such without. If no logistics is included the company holon has to find partner shipping companies when a transportation task is needed and therefore can use the logistics services of the market place. If the company has a logistics department but not enough resources left to fulfil a logistic task, the logistics department is responsible to find other shipping companies, that can do the job.

The logistics company has to co-ordinate, control and schedule the resources and is not involved in any trading process. These companies provide special services, which can be accessed by the other groups of the ITN. Such companies are also represented by a holonic mulit-agent system, which is quiet more complex then of the others. In the logistics part of the system each entity of the real world has its pendant in the multiagent system. This is necessary because of the huge amount of constraints of each entity that have to take into account during the planning and scheduling process. Especially in logistics there exists a large variety of machine-types and groups of persons, which have to be represented. Hence, each of the physical components of a logistics company and every employer is represented by an agent that administrates the resources of the component or person. These agents have their own plans, desires, constraints and goals, so that they are able to act autonomously during the planning and scheduling process of its own company.

For the distribution of tasks to this agent society the contract net protocol, a popular DAI allocation mechanism, can be applied, because the agents of a company behave co-operatively. In its original version [6] the protocol consists of a manager, who announces a task to a set of contractors (see figure 4). Based on their local cost estimations, these contractors compute bids, which are sent to the manager. The manager selects the best bid, rejects the others and grants the task to the best bidder. This contractor is committed to report the success or failure of the execution to the manager.

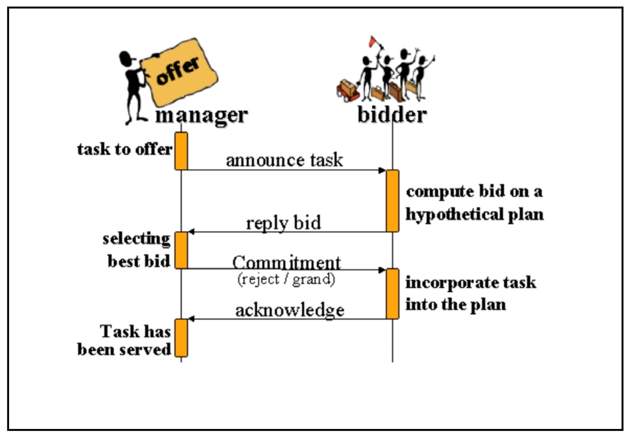

Figure 4. The contract net protocol.

The manager of the protocol is in our scenario the logistics holon agent, which encapsulates the internal agent structure to the outer world. The manager agent is therefore the coordinator of the other agents, representing the real world's entities. In the protocol these agents appear as bidders applying for the announced tasks. In such a co-operative setting, the contract net protocol is a simple method to find an allocation of a set of tasks to an agent society. But as the agents act independently during their decision process, the plans only become locally optimized. To achieve global optimality of the initial plans we intended the contract net protocol by incorporating simulated trading [1].

However, the extended version of the contract net protocol applied to the transportation domain turns out to be not suited when the environment gets more complex in a way that the actions of the agents are not independent from each other. This is the case, when machines and workers are represented separately and the elements of a combination (machine – worker) changes over time. Hereby the change in the plan of a worker might has an influence to the plan of another worker, who uses the same machine at a different time.

In our setting we have to face this problem and therefore have developed an efficient representation of the plan steps to include the interdependencies in the plan. This avoids us to consult all members of the convex hull over the dependencies beginning with the plan of that agent, which has to make a change. So for each request, normally the agent has to compute a new plan, on which it executes the request. But often these requests are only of hypothetical nature and after the answer of the agent is known, the effect of the request has to be discarded. This is often done during the execution of the contract net protocol, when the manager sends his announcement to all its sub-agents and after the answers are analyzed, only one agent gets a grant and the others have to discard their modifications.

By now when a modification becomes real and stable we have to find all the agents that are affected by the change of the plan. This has to be done after the modification is stable, so that afterwards the agents are able again to give answers to such requests.

3.3 Plan Representation

A plan (or schedule) is a representation of those future activities of an agent that are intended in order to perform the tasks the agent is committed to. The difficulty during the computation of plan is to find an adequate level of abstraction. An instruction like 'drive around, pick the goods and after that come back' is a plan, but it is too abstract to be of any use. On the other hand, a plan that specifies exactly for any point in time where the unit has to be and what the worker has to do, seems to be too precise. It is difficult to generate and to modify, and it is more hardly to execute, because no one is able to say exactly the time for the execution. In this setting there too many uncertainties.

The principle of least commitment planning is to make only necessary commitments during the planning process and to leave open as many degrees of freedom as possible. In order to be sure that the plan is feasible, the sequence of the driving and executing operations (e.g. load, unload, etc.) has to be fixed. The precise times for the actions can be left open within a limiting interval.

A tour plan in our system is represents:

- the sequence of locations the entity has to go (pos)
- the action operator for each of these locations
- the approximated time needed to reach the next location in the sequence (distance from a to b –dab)
- the duration needed for the processing at a location (dur)
- the amount of load at any time
- time window for each action (earliest start time – est, latest departure time – ldt)

A tour is a list of plan steps [p_1, p_2,... , p_n]. Each plan step represents one action. Besides the location (pos) the core parameter of the plan steps are the time (est, ldt, dur, dab) and capacity (weight, amount) constraints. Naturally, the planned time window [est, ldt] cannot exceed the time window specified in the order.

A tour plan is valid if the following constraints are fulfilled, otherwise it is invalid. For any plan step p_i the planned time window does not exceed the time window specified in the corresponding order (o).

$$o.est \le p_i.est \le p_i.ldt \le o.ldt$$

The duration of the operations is included in the [est, ldt] interval that is specified in the order as the time slot where the execution at the a given location (pos) is possible. The [est, ldt] window of any two successive plan steps p_i, p_{i+1} are constrained. The following equation represents the constraint that the operation of step p_{i+1} cannot start before the earliest time at which the operation at step p_i can be started plus the duration of the action execution at p_i plus the driving time needed between the two locations.

$$p_i.est + p_i.dur + p_i.dab \le p_{i+1}.est$$

Analogous represents the next equation the constraint that the start of an operation at step p_i cannot be delayed after the latest time to start the operation at p_{i+1} minus the driving time.

$$p_i.ldt \le p_{i+1}.ldt - p_{i+1}.dab$$

When the [est, ldt] time window in a plan is reduced, the other plan steps are influenced as well: A decrease of the ldt propagates backward to the ldt values of the previous plan steps. Analogous for est but from the point of disturbance the propagation goes forward in the plan.

The least commitment representation of the time slots guarantees flexibility during the plan execution. In addition this strategy allows to represent an amount of free time that is available to integrate additional plan steps. After an insertion the plan of an agent has to be re-computed regarding the time constraints of the other influenced agents. But this computation only has to be done after the plan is modified and for a simple request without insertion it is not necessary to re-compute the plan and solve all the dependencies between the other agents. So a request without insertion can be handled very quickly.

3.4 Plan Insertion Procedure

When a new plan step has to be incorporated into an existing plan of an agent there will be no problem as long as each agent is solely responsible for its plan. Hence, no other agent is affected by the changes to already existing plan steps. But if any dependency exists between the plans ("connected plan steps") of two or more agents, we have to be aware of consistency among their plans.

Consistency can be retained by following these two steps:

• Plan steps have to remain consistent among the society from the beginning (i.e. the empty plan) on. In detail, whenever a plan step requires the action of more than one agent then this plan step has exactly the same parameters (start time, duration, end time) in each of the related agents' plan. Hereby the setting of the correct parameters is done by a central coordinating agent during the matching phase within a contract net protocol. Thus whenever a request for an insertion is issued the agent can decide on his own if it is possible to grant this request. This prevents that an agent A_1 grants the request because it could adjust its plan steps in a way that an insertion is possible, while these changes make it impossible for another agent A_2 to fulfill its plan because it cannot change its plan step parameters accordingly. For instance because of other already inserted plan steps which are not shared with agent A_1.

- Any changes of plan steps have to be propagated to the other agents of the society. This prevents connected plan steps from becoming inconsistent within the different plans of related agents. In detail the following describes, what has to be done whenever a new plan step is inserted or deleted in an agent's plan:

Each agent, which makes changes on its plan, re-computes it independently from the others even if they have some relations to this agent. Then all changed steps are collected, sorted according to the related agents and sent to each of them in a single message. Thus the update process is independent from the number of changed plan steps and so only depends on the number of agents in the society (quadratic runtime).

When an agent receives such an update message it checks its own plan if the received changes narrow the time slot of an existing plan step; if so, it adopts the new times. Otherwise it does nothing.

When all messages have been sent and been processed, the plans of all agents are consistent again (remember that only narrowing time slots were allowed in the update process).

4. CONCLUSION

We presented an agent-based approach for integrating logistics services into a B2B marketplace to offer agent-based services in the field of electronic commerce to make the logistics more transparent to the seller and buyer, who uses a virtual market place. Another objective in this setting is to establish an information and trading network which offers public market places with several auction mechanisms in combination with mobile services. The auction mechanisms are expanded by integrated services, enabling their users to adept their bidding strategies to the availability and costs of logistics services during auction. The openness, scalability and negotiation abilities of a holonic multiagent systems build the basis for the realization of this scenario. The central competence of a logistics company is the service of delivering goods. Therefore the most important business process for such companies is the timely execution of the shipping tasks. This process consists of receiving orders, building plans and schedules to incorporate them, execution of the plans and re-planning and adjusting the plans while controlling the execution. This process is heavily sequential, complex and a large amount of resources, constraints and interdependencies have to be faced during the process execution. The efficiency of a dispatcher can be improved by providing services for fleet management and other logistics tasks. These services also have interfaces to the logistics services of our market place that a transportation request from a seller or buyer can be directly forwarded to logistics companies .

5. REFERENCES

[1] Bachem, A., Hochstättler, W., and Malich, M., Simulated Trading: A New Approach For Solving Vehicle Routing Problems. *Technical Report* 92.125, Mathematisches Institut der Universität zu Köln (1992).

[2] Bürckert, H.-J., Fischer, K., and Vierke, G., Transportation Scheduling with Holonic MAS — The TeleTruck Approach. Proceedings of the Third International Conference on Practical Applications of Intelligent Agents and Multiagents PAAM´98, (1998).

[3] Bürckert, H.-J., Fischer, K., and Vierke, G., Holonic Transport Scheduling With TELETRUCK. *Applied Artificial Intelligence*, **14**, (2000), pp. 697-725.

[4] Gerber, C., Siekmann, J., and Vierke, G., Flexible Autonomy in Holonic Agent Systems. Proceedings of the 1999 AAAI Spring Symposium on Agents with Adjustable Autonomy, (1999).

[5] Klusch, M., Bürckert, H.-J., Gerber, A., Russ, C., Applications of Information Agents and Systems. In: L.C. Jain (ed.), *Practical Applications of Intelligent Agents*, (Springer, 2002).

[6] Smith, R. G., The Contract Net Protocol: High-Level Communication and Control and a Distributed Problem Solver. In IEEE Transaction an Computers, number 12 in C-29, pp. 1104-1113. 1980

[7] Warzecha, A., The Content of E-Business, *Internet Content Management 2001,* Boston, MA