

E-Supply Chain Management using Software Agents

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Abstract- Today enterprises are facing increasing problems in adapting to sudden changes in the market requirements as also to cater to multiple geographies and to shorter product lifecycle times. Various supply chain problems like parts paucity, excessive finished good inventories, unused plant capacity, excessive warehousing costs, and inefficient transportation of supplies and finished goods are causing huge losses to companies. E-supply chain management using software agents has the benefit of solving the tasks by various participants in the supply chain network through their local intelligence and problem-solving paradigms. Using agent-based technologies, various stakeholders, suppliers, manufacturers and transporters can negotiate through dialogue and interaction mechanisms and distribute various activities in a decentralized manner more efficiently. Applications of software agents in various activities of the supply chain like production planning, production monitoring, workflow modeling, negotiation, logistics, scheduling and transportation management are explored with case studies of lieve systems like AARIA, CAPPs and PROSA. However it is also observed that the use of software agents has not moved beyond some usages in enterprise integrations and supply chain networks to complete end-to-end shrink-wrapped software solutions

Keywords- agents, e-supply chain, intelligent agents, multi-agent systems, negotiation, scheduling

I. Introduction

A software agent is a software system, which has attributes of intelligence, autonomy, adaptability, perception or acting on behalf of a user. Agents can behave autonomously or proactively. The intelligence of an agent refers to its ability of performing tasks or actions using relevant information gathered as part of different problem-solving techniques such as influencing, reasoning and application specific knowledge.

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Agents can adapt or learn through the choice of alternative problem-solving-rules or algorithms, or through the discovery of problem solving strategies. Learning may proceed through trial-and-error. Alternatively, learning may proceed by example and generalization, and then it implies a capacity to abstract and generalize. Agents could be “autonomous”, when self-contained and capable of making independent decisions, and taking actions to satisfy internal goals based upon their perceived environment.

One classification of agents given by [1] suggests that there are four essential types of intelligent software agents:

- Buyer agents or shopping bots - Buyer agents travel around network (i.e. the internet) retrieving information about goods and services. Amazon.com is a good example of a shopping bot. The website will offer you a list of books that you might like to buy on the basis of what you're buying now and what you have bought in the past.
- Monitoring and Surveillance Agents are used to observe and report on equipment, usually computer systems. The agents may keep track of company inventory levels, observe competitors' prices and relay them back to the company.
- User agents (personal agents) - User agents, or personal agents, are intelligent agents that take action on your behalf. In this category belong those intelligent agents that perform tasks like checking your e-mail and sorting it according to the user's order of preference, Assemble customized news reports for you. There are several versions of these, including newshub and CNN.
- Data mining agents - This agent uses information technology to find trends and patterns in an abundance of information from many different sources. The user can sort through this information in order to find whatever information they are seeking.

II. Software Agent-Based Approach in Supply Chain Management

Software Agents are being used in an increasingly wide variety of applications — ranging from comparatively small

systems such as personalized email filters to large, complex, mission critical systems such as air-traffic control.

Today enterprises are facing increasing problems in adapting to sudden changes in the market requirements as also to cater to multiple geographies and to shorter product lifecycle times. One study by [2] has found that companies lose between 9% and 20% of their value over a six-month period due to supply chain problems. The problems range from parts paucity, excessive finished good inventories, unused plant capacity, excessive warehousing costs, and inefficient transportation of supplies, work-in progress and finished goods.

Traditionally, supply chains have been formed and managed by means of human interactions. But the increasing demand for swift-decision making in the face of increased competition, rapid globalization and complexity of information, is creating a need for an advanced support in automating supply chains and creating e-supply chains. Fluctuations in resource availability drive companies to respond rapidly to maintain their production capabilities. As these changes increasingly occur at speeds and complexities unmanageable by human intervention, the need for automated supply chains becomes all the more critical.

The traditional approach to supply chain management requires a central authority that creates planning and decision-making functions, which are to be propagated into the supply network. This requires delegation to sub-tasks by the central authority. However a decentralized approach has the benefit of solving the sub-tasks by various participants in the supply chain network through their local intelligence and problem-solving paradigms. Using agent-based technologies, suppliers and manufacturers can negotiate through dialogue and interaction mechanisms and distribute various activities in a decentralized manner more efficiently [3].

Attempts to automate solutions to these problems are also complicated by the need for the different companies in a supply chain to maintain the integrity and confidentiality of their information systems and operations. The modeling technologies currently used within the manufacturing business-to-business standards communities — such as the Open Applications Group (<http://www.openapplications.org>) and RosettaNet (<http://www.rosettanet.org>) — do a good job of capturing user requirements. Unfortunately, current technologies do not explicitly link the requirements to formal process models. This missing link is crucial to efficient SCM implementations.

One way to automate supply chains is to gather companies into e-marketplaces (such as Chem-Connect, <http://www.chemconnect.com>, for chemicals and Covisint, <http://www.covisint.com>, for automotive supplies), where they can negotiate for goods and services [4]. However,

because companies must participate independently, such centralization does not foster the kinds of alliances or long-term relationships that can significantly improve supply-chain efficiency.

Agents have a high degree of self-determination; they can decide for themselves what, when and under what conditions their actions should be performed. Also dynamic interactions with other such intelligent autonomous agents help in arriving at optimum course of actions or agreements. Thereby the agent-based approach offers opportunities to create a virtual market place in which a number of autonomous or semi-autonomous agents can trade services efficiently. Agents can not only eliminate the need to manually pass information about various actors and processes, but also allow negotiation on optimal prices within various stakeholders in the supply chain. In such a situation, the entire supply chain management process becomes a multi-agent system.

Monitoring and Surveillance agents and Data mining agents have been used applications in SCM. For example, NASA's Jet Propulsion Laboratory has an agent that monitors inventory, planning, and scheduling equipment ordering to keep costs down, as well as food storage facilities. Air Liquide America LP, a producer of liquefied industrial gases, reduced its production and distribution costs using agents. Merck and Co, a leading research-driven pharmaceutical company used agents to help it find more efficient ways to distribute anti-HIV drugs.

However as per [5], use of software agents has not moved beyond some usages in enterprise integrations and supply chain networks to complete end-to-end shrink-wrapped software solutions

III. Software Agent Application Areas in Supply Chain Management

There are several typical application areas of the software agent technologies that relate to manufacturing and managing the supply chain.

In production when we need highly complex planning problems to be solved, we need to control dynamic, unpredictable and unstable processes. Software agents allow for the implementation of distributed planning and control algorithms. As per [6], agents can act autonomously and also ensure through their communication abilities a co-operative behavior. In production there is also a potential for agent-based diagnostics, repair, reconfiguration and replanning. Another advantage of agent-based approach is its ability to process relevant production data, distributed across the entire enterprise or supply chain.

Software agents can also be employed in production monitoring tools that support manufacturing decisions only based on production quantities. In case of a facility breakdown or quality inspection results they only know that a certain number of vehicles is affected but neither the customer orders related to these vehicles nor their options, e.g. color, right hand-/left hand drive, sun roof, etc. It would be a great step forward for better and more transparent decisions if the shop floor people could take their decisions based on identified vehicles/customer orders rather than on undefined production quantities. These agent-based production monitoring systems play a relevant role in supporting the manufacturing operations; and, what is more, they can be seen as the operational part of the digital factory [7].

Multit-agent systems (MAS) can be used for job shop scheduling. This is done by coordinated conflict resolution in the iterative and asynchronous multi-agent decision-making process [8].

In the domain of virtual enterprises and supply chain management there are requirements for forming business networks and alliances, planning long-term/short-term collaboration agreements, reconfiguration and dissolution of supply chains. Here we also can use various agent technologies for agents' private knowledge maintenance, specification of various ontologies and ensuring service interoperability across the supply chain.

The multi-agent technology can also be used for creating virtual organizations. Similarly to agentification of the factory legacy systems or hardware machinery, one can integrate ERP systems of collaborators, suppliers and customers. Integrated supply chain management requires solution for security and authentication, trust, long term business processes optimization, ubiquity and openness

In the domain of internet-base business agent technologies can be used for intelligent shopping and auctioning, information retrieval and searching, remote access to information and remote system control.

Another important application domain is logistics. MAS can be used for managing transportation networks and material handling, optimal and robust planning and scheduling, especially in cargo transportation, public transport but also peace-keeping missions, military maneuvers, etc. There is a nice match of the agent technologies and managing of the utility networks such as energy distribution networks, mobile operators networks and cable provider networks. Here the concept of distributed autonomous computation can be used for simulation and predication of alarm situations, prevention to black-out and overload and intrusion detection [9].

Negotiation is another critical area of application of MAS for SCM. Companies are required to comply with customer orders even if it may be hard to do so. Companies have to respond to the orders quickly and efficiently in the limited time available to fulfill the customer's requirements. Unexpected rush orders, however, in most circumstances causes delays in delivery and decreases efficiency in all of the supporting members. To coordinate different supply chain entities and solve these problems, negotiation decisions have been identified as crucial for successful global manufacturing. Negotiation techniques are used to overcome conflicts and coalitions, and to come to an agreement among agents, instead of persuading them to accept a ready solution [10].

iv. Available Systems and Implementations

Classical planning systems (using scheduling algorithms with various heuristics, constraint logic programming, genetic algorithms, and simulated annealing) work centrally and allocate resources usually in one run for every product order in the system. These methods use mostly stochastic algorithms and generate near-optimal solutions to minimize the defined criteria for example, sum of weighted tardiness and inventory costs). Such solutions are fully sufficient for planning in stable environments. However, in an environment with requirements to continually revise the plan, these approaches would breach the calculative rationality requirement (the minimal time required or two relevant changes in the environment is larger than the maximal time needed to process the change). When replanning is required, the plan is usually completely rebuilt and the algorithms' random aspect can cause major, unwanted changes, which makes this approach unsuitable for many manufacturing areas. For physically distributed production units, it's advantageous to break down and distribute the planning problem [10].

Multiagent technology can address a wide range of manufacturing decision-making support problems, but few MAS implementations cover more than a single type of a problem. Solutions exist for low-level scheduling or control systems as well as product-configuration and quotation phases for short and long-term production planning and supply chain management.

A. *Autonomous Agents at Rock Island Arsenal (AARIA)*

AARIA is a product of Agent research conducted at University of Cincinnati. Rock Island Arsenal is a military production facility used to demonstrate results of the research. The system interconnects manufacturing processes implemented as agents to outperform current, centrally-

controlled manufacturing systems. This is done by allowing quick reconfiguration to optimize profits and allow customization in a dynamic business climate [11]. The AARIA system integrates manufacturing capabilities (for example people, machines, and parts) in a MAS so that each agent interoperates with other agents in and outside its own factory. AARIA uses a mixture of heuristic scheduling techniques: forward and backward, simulation and intelligent scheduling.

B. Collaborative Agents for Production Planning and Scheduling (CAPPS)

CAPPS is a system developed for manufacturing companies in Japan. This addresses production scheduling by using agents to clarify relationship among production items and manufacturing resources in the time horizon, concerning various constraints and objectives of production [12]. Considering the frequent changes in market needs, real-time production management will produce huge additional value for manufacturers. As scheduling of shop floor operations is a local and partial decision in enterprises, the distributed local scheduling problems should be integrated at the enterprise level. Since decisions at the shop floor are very valuable, the next generation of production management will be performed as a decentralized system. CAPPS uses collaborative agents for production planning and scheduling and achieves system integration by communication among agents.

C. Products Resource Order Staff architecture (PROSA)

PROSA is reference architecture for manufacturing control built by European researchers. It's mainly oriented to interholon architecture and identifies kinds of holons (agents) — their responsibilities, functionality, structure, and interaction protocols. PROSA defines three main classes of holons: product, resource, and order. Product agents manage production procedures and process techniques—for instance, which operations to perform to achieve the product. Resource agents represent resources such as machines. Order agents represent manufacturing orders and are responsible for following deadlines. The PROSA architecture also designed staff agents to give the previous basic agents sophisticated knowledge support. However there are some drawbacks of this system which include the possibility of a community with numerous agents (according to the size of the factory and number of products) with unpredictable behavior [5].

v. Conclusion

The supply chain is a worldwide network of stakeholders like manufacturers, suppliers, factories, transporters, warehouses and retailers through which raw materials are acquired, transformed, and delivered to customers. To optimize performance, supply-chain functions must operate in a coordinated manner. But the dynamics of the enterprise and the market make this difficult. There are part shortages, materials do not arrive on time, customers change or cancel orders and so forth, causing deviations from the plan.

In recent years, e-supply chains through implementations of innovative software agents and its networks have shown to improve supply chain planning and execution. It views the supply chain as composed of a set of intelligent software agents, each responsible for one or more activities in the supply chain and each interacting with other agents in the planning, negotiation and execution of their responsibilities. Software agents have been increasingly explored to improve the information flow and the decision-making process through negotiation within networked enterprises. Typical applications of software agents in the various processes of supply chain management include production planning, production monitoring, e-collaboration, negotiation, logistics, scheduling and transportation management. However considering the vast benefits, enterprise implementations and deployments of software agents for supply chain management is limited.

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