Proceedings of the 2001 Winter Simulation Conference
B. A. Peters, J. S. Smith, D. J. Medeiros, and M. W. Rohrer, eds.

SUPPLY CHAIN AGENT DECISION AID SYSTEM (SCADAS)

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ABSTRACT

Supply chain decisions are improved with access to global information. However, supply chain partners are frequently hesitant to provide full access to all the information within an enterprise. A mechanism to make decisions based on global information without complete access to that information is required for improved supply chain decision making. Mobile agents can support this requirement and these are the programs that can be initiated on a single host and then migrate from host to host over a network. At each host, a process can be spawned which will provide a "black-box" view into that host's information. This provides access to necessary information, while maintaining privacy for company sensitive information. This paper will discuss mobile agents and how they are useful in designing and managing the supply chain. The Supply Chain Agent Decision Aid System (SCADAS) is presented as tool to provide the flexibility of mobile agents while protecting company sensitive information.

1 INTRODUCTION

In today's competitive environment, single enterprise acting alone can no longer provide maximum value to many of today's demanding customers. Enterprises are therefore increasingly participating in extended supply chains. "A supply chain is a web of autonomous enterprises collectively responsible for satisfying the customer by creating an extended enterprise that conducts all phases of design, procurement, manufacturing, and distribution of products " (Whitman et al., 1999b). To maximize value to the customer, the entire supply chain must be 'optimized.' A supply chain will continually lose market share if each component of the supply chain is not involved in continuous improvement. The supply chain design must be flexible to meet changing customer demands. To meet these needs the entire supply chain must be able to respond according to each member's core competencies. In this paper we propose a framework and elaborate on its applications and tools that utilize these agents while maintaining company sensitive information.

1.1 Supply Chain Models

Many supply chain models are in reality network design methods. These methods consider the flow of materials between the location of suppliers, inventories, production factories, and warehouses. Network design methods in supply chains frequently become large-scale problems. Following is a summary of these methods.

Zangwill (1969) proposed a deterministic multi-product, multi-facility production, and inventory model. The model considers concave production costs, which can depend on the production in several different facilities, and piecewise concave inventory costs. Furthermore, backlogging of unsatisfied demand is permitted. This study is focused on determining an optimal production schedule, which specifies how much each facility in the network should produce so that the total cost is minimized.

Cohen and Lee (1988) developed a model structure that can be used to predict the performance of a firm with respect to 1) cost of its product, 2) the service level, and 3) the responsiveness and flexibility of the production/distribution system. They represented an integrated, hierarchical, and stochastic network model structure consisting of four sub models, where each represents a part of the overall supply chain network. The four sub models are: 1) material control sub model, 2) production control sub model, 3) finished goods stockpile sub model, and 4) distribution network control sub model. They used heuristic methods to connect and optimize all four sub models.

Farkas, Koltai, and Szendrovits (1993) presented a case study about linear programming optimization of a network for an aluminum plant. The mathematical structure of their problem is a generalized network with constraints such as capacity constraints and flow constraints between each node. They used linear programming to optimize the objective function that includes 134 decision variables and 142 constraints. This study considers only a deterministic case.

Some models represent more than just the supply chain network. Whitman, et al., propose a standard model as an analysis tool to aid in the initial as well as the ongoing configuration of the supply chain (Whitman et al., 1999a). The model itself can be a useful communication tool to aid in developing a common understanding of any situation including that of supply chain. A suite of supply chain models must represent all three levels; strategic, tactical, and operational (Fox et al., 1993). Supply chains are, by their very nature, extremely complex. A model of the supply chain can greatly reduce this complexity.

This section presented a sample of methods used to develop a model for the analysis of a supply chain. Each of these efforts presented a different model of the supply chain and it is difficult to compare techniques. The next section discusses mobile agents and how these agents can aid in supply chain decisions.

1.2 Mobile Agents

"The importance of agent technology is not hard to predict, since shock waves are already being felt throughout the computer industry. A steadily increasing number of research projects, prototypes and even products containing, or claiming to contain, agent technology are being announced almost daily, and autonomous mobile agents are beginning to appear on the internet" (Kalakota et al., 1996).

Mobile agents are the independent programs or mobile codes that can travel from one network to another while performing different kinds of operations. Mobile agents have the inherent capacity to pack a conversation and dispatch it to a destination system, where the interactions can take place locally. The idea is simply to move the computations to the data rather than the data to the computations. The issues associated with designing agent-based systems for supply chain management include network intelligence to handle networking issues of security, reliability, authenticity, integrity and management of information (Kalakota et al., 1996).

Information can also be accessed globally by using different types of devices like mobile phones, personal digital assistants, digital diaries, laptops and workstations. In this rapidly changing world, adaptability and flexibility are the major requirements for the distributed system. In traditional systems like the client/server model for distributed systems, various pre-programmed interfaces define the communication system. All the interfaces are pre-programmed to know how to use the resources at each system, how the flow control must be established and what information can be shared by using protocol properties like windowing and resource reservation (Kalakota et al., 1996).

However, the new distributed systems that are based on mobile agents can easily set up direct access between client and server. The mobile codes that carry the communication link and other required information with them could migrate anywhere in the system by maintaining their same state of execution (Kalakota et al., 1996). The same state of execution means that if the code is executed forty percent on one system then it can go to some other system and resume its execution where it left off at the previous system.

2 MOBILE AGENTS IN THE SUPPLY CHAIN

Supply chain decisions are improved with access to global information. However, supply chain partners are frequently hesitant to provide full access to all information within a single enterprise. A mechanism to make a decision based on global information without complete access to the information will create an improved supply chain decision-making environment.

Mobile agents are programs that can be initiated on a single host and then migrate from host to host over a network. Rules can be established to determine the migration path wherein the mobile agent determines its own next host. At each host a process can be spawned, similar to some decision support system. They will provide a "black-box" view into that host's information. Since only the result of the query is needed by the mobile agent, complete information viewing is not necessary. The process views the required information and returns only the results. This provides access to the necessary information, while maintaining privacy for company sensitive information.

"Mobile agents can act as local representatives for remote services, provide interactive access to data they accompany, and carry out tasks for users temporarily disconnected from the network" (Thomsen and Thomsen, 1987).

An electronic marketplace is a system consisting of multiple agents that interact with each other in order to buy or sell something on behalf of their users. Recently, an IBM team has developed an electronic marketplace framework for conducting global business more safely and efficiently (Lange and Oshima, 1998).

The framework is mainly designed considering the advantages of conventional business systems that involve marketplace owners, shop owners and consumers. The overall infrastructure is maintained by marketplace owners. Shop owners are the agents that want to sell something on behalf of their users and consumers are the agents those indulging in the buying activities as shown in Figure 1.

First, the shop agents go to a market (Centralized Market server) from the shop owner's computer to buy the required product. Secondly, the customer agents roam around various marketplaces to get more information. Lastly, market agents go to other markets to advertise about their market and to invite customer agents. In a marketplace the shop agent and consumer agent can negotiate with each other in terms of cost, quality and service just like a normal business. "Since the agents can be developed independently, the agent system is made flexible in the sense that adding a new agent or updating an existing agent can easily modify its behavior. For example, one should be able to replace a shop or a customer agent with an updated agent as long as the new agent behaves in accordance with the defined interaction protocol" (Lange and Oshima, 1998).

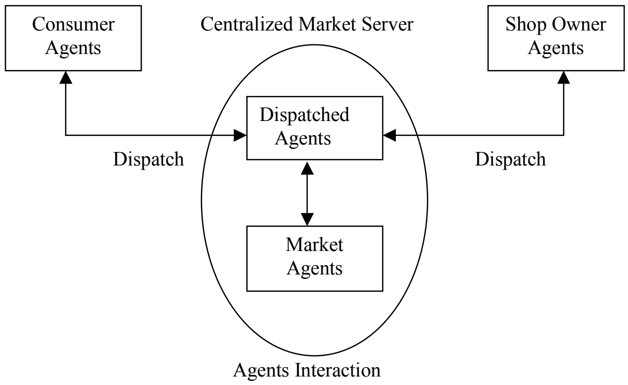

Figure 1: The electronic marketplace

2.1 Virtual Factory

"A virtual factory is defined as a community of dozens of factories each focused on what it does best, all linked by an electronic network that would enable them to operate as one – flexibly and inexpensively regardless of their location" (Brugali et al., 1998). A virtual factory is basically used in a distributed environment to enhance distributed decision making and planning. Mobile agent technology is one of the available tools that is used to enhance the communication and coordination in a distributed system to ensure efficient decision-making and distributed job planning.

This technology is used in several European textile-manufacturing firms to integrate their production control and marketing activities. The wool industry where fashion and style changes quite frequently requires fast scheduling and delivery periods. "The market requirement is therefore for an interconnecting network where product data coupled with a strongly integrated scheduling of the production between retailers, the garment producer and its suppliers, commission transformers and customers, reduces the time between securing an order and delivering the product to a minimum" (Brugali et al., 1998).

Some specific properties of the distributed system should be kept in mind while designing the framework for the factory's information model. The framework should be heterogeneous in terms of design so that it can accommodate various languages and operating systems. It should be scalable so that it can easily be updated at various stages without affecting the other components. It should also be re-configurable so that it can modify itself according to the market dynamics. Apart from this it should also be secure and easily accessible in order to protect the system from hackers and other competitors.

The agent-based framework is categorized into three levels. It includes the supply chain level, the factory level and the user level. At the supply chain level, only static agents play role in managing the product and information model to integrate it with factory's enterprise resource planning (ERP) system. It also facilitates providing the assistance for mobile agent execution environment on the factories computer. The other level, which is called the factory level, includes the hierarchical control modules at every level. At the user level interface, the mobile agents assist the user in retrieving information through the supply chain with the help of a web browser. They act like an interface between the user and factory agents (Brugali et al., 1998).

Agents are also used in implementing real time supply chain optimization systems. Broadly, the information system is divided into two parts, one is the static information model and other is the dynamic information model. The static information system involves making requests, processing the request and delivering the response. On the other hand in the dynamic information system, real time data is taken into account. In the age of global interconnectivity, a huge amount of data is available on the web. Through the effective use of electronic data interchange, a factory can track the amount of inventory in its warehouses, retailers and distributors very easily. Based on that inventory, effective forecasting regarding sales and production can be done.

For example, several types of agents can be used to keep track of various systems. An inventory agent can be used to keep track of raw material. Whenever the inventory goes below a certain level, the inventory agent becomes active. It can automatically write up an electronic request to the supplier for the required material.

2.2 Agents in Manufacturing

Agents have also revolutionized manufacturing systems. In distributed intelligent manufacturing systems, the main function of agents is to integrate manufacturing enterprise activities such as design, planning, execution, simulation, distribution, forecasting between suppliers, customers and partners via a network. They are also used to represent various manufacturing sources like products, parts and operations to facilitate different manufacturing activities.

The agent based manufacturing systems can be classified according to their system architecture: the Hierarchical approach, the Federation approach and the Autonomous agent approach. A combination of hierarchical and semi-autonomous agents is used in typical modern manufacturing enterprises. In the Facilitator approach, several related agents are combined into a group. An interface called a facilitator helps these agents in communicating with each other. The main function of a Facilitator is to route outgoing messages to the correct destinations and to translate the incoming messages for consumption by its agents (Shen and Norrie, 1999).

Real world manufacturing environments are highly dynamic because of diverse and frequently changing situations: changing bank rates, changing political environments, materials do not arrive on time, power supplies breakdown, production facilities fail, worker absenteeism, new orders arrive and existing orders are changed or cancelled. Such changing situations lead to deviations from existing plans and schedules. It is therefore necessary for the system architecture to meet such requirements and for the working system to adapt to such changing environments (Shen and Norrie, 1999).

3 RESEARCH METHODOLOGY

This section provides detail on the approach taken to utilize mobile agents in supply chain decisions. The basic philosophy is that the simulation tools that support object linking and embedding (OLE) can be controlled on the web. To control such tools on the web, an object linking and embedded controller is required. Visual Basic is one of the most frequently used OLE automation controllers. Many of the commercial simulation packages as well as other decision-making tools allow users to develop macros to 'automate' some tasks. The variables used in the models can be manipulated using macros over the web. These macros are similar to certain programming languages (in fact the most common macro language is a subset of one of the most popular programming languages, Visual Basic). Our approach is to extend this capability over the web and to introduce mobile agents to interface between various similar and dissimilar tools.

The project is divided into four phases. The first phase consists of registering the simulation software ('Witness' in our case) as a server (OLE automation sever) on a web server. To register the server, enter the statement, "C:\witness\witness.exe /Regserver" at the command prompt.

The second phase consists of creating a simulation model, which is not required if it already exists. During initialization, the simulation model must utilize variables that are controlled by statements.

The third phase consists of developing a Visual Basic Active-X application, which is further embedded in an HTML form containing all the information, which is required to control the simulation. The application has to be initialized on a web server by selecting proper controls on a remote host from which the application is controlled. The *.ocx (Active X file) file should reside on the web server. Also, the OCX file must be registered using the 'regsrvr32.exe' command. Alternatively, ActiveX registration must be performed before an ActiveX (OCX) file can be used.

Finally, the HTML form must be integrated with mobile agents (IBM's Tahiti Server) by using JAVA Aglet technology to transfer the information to a web server and vice versa. In our application, the Tahiti server should be running on the client as well as on the web server. This requires each client (user) machine to install the Tahiti server. Tahiti was chosen because of its compatibility with JAVA. JAVA aglets are used to provide mobile agent technology.

This method allows greater flexibility as the remote user can control the simulation according to his needs. It will continue receiving feedback regarding the simulation with the help of intelligent mobile agents. The remote user has access to the feedback without requiring access to the entire knowledge base within the details of the simulation.

Combining existing simulation models and simulation skills, the Supply Chain Agent Decision Aid System (SCADAS) is developed using the above approach. SCADAS can be used to make both long-term and short-term decisions as discussed in the next section.

4 WAP BASED DECISION AID SYSTEM

For information to become knowledge, it should move. And of course it should move on time. The transformation of information into knowledge, knowledge into business and learning the transformation of information into knowledge is a critical part of supply chain management process (Bellmann, 2001). Making faster and up to date decisions based on the real time information can improve the overall supply chain process. An alternative method of initiating a remote simulation and then getting the results irrespective of users location is through the use of a technology called Wireless Application Protocol (WAP). The rest of this section describes about the methodology to initiate supply chain decision aid system with the help of a mobile device (e.g., mobile phone).

In an online dedicated system, the user has to monitor the simulation process continuously, consuming valuable man-hours. What is needed is a WAP based decision aid system that saves valuable man-hours. The concept of 'Mobile employees' is introduced that can more efficiently contribute to the growth of an enterprise.

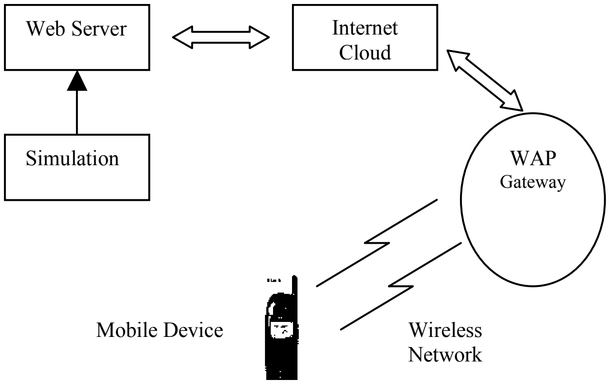

Figure 2: WAP based SCADAS Framework

A WAP based SCADAS application framework as shown in Figure 2 consists of a web server that contains the simulation program, which is connected to the IP (Internet Protocol) cloud. The IP cloud is connected to a WAP gateway and the WAP gateway is responsible for relaying the information through a wireless medium to the handheld device. Communication between wireless networks and the Internet is set up via WAP. The bridge between the Internet and the wireless network is known as the WAP-gateway. This gateway provides an interface between telecommunications protocols within the mobile operator's network and Internet protocols. It translates requests from WAP's protocol stack to the WWW protocol stack (HTTP and TCP/IP) (Stark, 2000).

Such a framework should not adhere itself to any centralized concept and provide for developing totally scalable, fault-tolerant, self-configurable and flexible decision aid system.

Each of the following subsections describes how this framework should address these basic implementation issues of 1) Communication protocols, 2) Interaction, and 3) Two-way push and pull communication.

4.1 Communication

Communication enables the use of the wireless application protocol in order to convert the information from a wireless network to a normal IP (Internet Protocol) based system and vice versa. The limits for all the resultant simulation values have been established in advance and whenever that limit is reached an alert message is relayed to the mobile device. In this framework two different approaches are considered for relaying the message. The first one is the Visual Basic activated Text2GSM™ (A Short Messaging Service enabled software) software that is used to relay the messages whenever the preset limits are reached. The second approach is using mobile agents to relay the messages. But one of the drawbacks of this system is that it only works from PC to PC and not from PC to a mobile device.

4.2 Interaction

The results generated by the simulation process are stored in an Oracle database. The interaction between different data objects is achieved through Oracle triggers. In a real time environment, the inherently heterogeneous and distributed nature of the database system makes the implementation of the interaction mechanism among triggers a difficult process. A user-friendly front-end system is designed so that the user can setup various parameters for the simulation process. The front hand system is designed using WML (Wireless Mark-up Language), since mobile devices can understand only WML.

4.3 Two-Way Push and Pull Communication

Both the technologies have been considered for information transfer. Push framework (WAP forum, 1999) is used when the mobile alerts are sent to the user's mobile device while a pull framework is used when the user is accessing the corporate database and trying to initiate a simulation process.

The design methodology will remain almost the same as SCADAS except that in place of HTML code, this time the server application will be throwing WML codes so that a mobile device can process these codes.

5 APPLICATION

Within the supply chain several different types of information can be exchanged. Young (2000) claims that "the better a group of organizations becomes at passing information throughout the supply chain, the more efficient that supply chain becomes". He then lists in ascending order of importance, the types of information shared in a supply chain. These are: transaction information, short-term scheduling, long-term planning, facilities and/or infrastructure network information. There is much in the literature regarding long term planning and facilities and infrastructure network information. Enterprise Resource Planning systems are designed to deal with transactions. This research deals with both long-term planning and short-term scheduling issues. Most of the supply chain decisions are made assuming a static model. This case study shows how SCADAS would be applied in a dynamic environment for both long-term and short-term decisions.

Capacity, long considered the bane of Material Requirements Planning (MRP) systems, is still a fundamental issue in the supply chain. In both 'internal' and external supply chains, many decisions hinge on capacity issues. Capacity depends on many different parameters, some, over the short term, fairly stable and others very dynamic. Modeling these parameters can cause quite a challenge. This data is also frequently considered proprietary and each link in the supply chain is hesitant to share these details. The following section describes a scenario where capacity issues may be addressed using SCADAS.

A standard schedule with standard order quantities is typically negotiated between supply chain partners. These partners agree to these terms with an understanding of the current business environment. The business environment can change, and frequently does change with opportunities arising out of unknown market segments. Decisions must be made to determine if current capacity throughout the supply chain can support the additional business.

Each supply chain partner has decision tools available to answer capacity decisions. If they do not have these tools available, then a tool can be developed to support these decisions (alternatively, the mobile agent could present an executable email message or form to a decision maker at the partner's site to respond to the capacity decision).

The scenario involves the end customer of a supply chain trying to decide if it should enter a new market. The question is, "Do I (we) have the capacity available to meet expected demand and can we do it cost effectively?" There are certain internal capacity questions that must first be answered. Internal tools are consulted and if the answer is positive, then the supply chain must be consulted. SCADAS then is launched and internal applications are consulted again for verification purposes. SCADAS queries a simulation tool used to schedule the bottleneck department in the company. Additionally, a decision support tool is queried to determine plant capacity. The parameters gathered here are encapsulated in the mobile agent, which then traverses the external network to several key suppliers host computers. After security has recognized the agents' authority and granted the appropriate access to only the required internal systems, their plant wide simulation communicates with the agent. The agent has no knowledge of how the parameters passed are used, it simply submits the parameters and awaits the result. In this case, the results demonstrate that capacity is available with some uncertainty in a certain area of the plant. The mobile agent traverses the plant network to the appropriate decision tool with an additional level of detail and submits the updated parameters. After receiving positive results, the mobile agent leaves the network of the supplier's facility and then travels to other key supplier networks. This process continues until a level of certainty is reached and a decision can be made at the end customer facility.

The agent leaves behind an audit trail for each plant to verify the accuracy of the results, but allowing the end customer to make the decision in a timely manner. The information is presented to the final decision maker in the format that is useful and timely.

6 CONCLUSION

"The ability to learn faster than your competitors may be the only sustainable competitive advantage" (Martin, 1995). Dynamic business environments challenge enterprises in many ways. There are compulsions to come up with new products for new markets and new customers. New alliances, mergers and partnerships have to be formed and new competition has to be faced. These challenges create a great strain on the existing supply chains. There is a dire need for an application technology that can make quick intelligent decisions based on real time information whenever there is such a need. Such technology will prove the competitive edge of one company over another. In any case this technology has to cost less than the value it creates to prove profitable for business.

The supply chain systems developed with software agents capture generic supply chain processes, which speed up modeling and quality decision making of supply chain systems. However, security and compatibility are two major risk factors with mobile agents that need to be resolved for better operation and acceptability. With the advent of mobile agent technology the method to integrate and optimize the global production and distribution supply chain has being revolutionized. The agent technology gives a powerful approach to support supply chain information architecture.

ACKNOWLEDGMENTS

This research was funded in part by the National Institute for Aviation Research.

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