Multi-Agent Supply Chain Management: Design Issues for a Generic Architecture

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Abstract

The supply chain is a worldwide network of suppliers, factories, warehouses, distribution centers, and retailers through which raw materials are acquired, transformed, and delivered to customers. Supply Chain Management (SCM) is extremely important to the manufacturing and retailing industries. In recent years, a new software architecture for managing the supply chain at the tactical and operational levels has emerged.

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 and execution of their responsibilities.

This paper investigates issues for the construction of such an agent-oriented software architecture.

Key Words: *Multi-agent systems, software agents, coordination, supply chain modeling, supply chain planning*

1. Introduction

The supply chain is a worldwide network of suppliers, factories, warehouses, distribution centers, and retailers through which raw materials are acquired, transformed, and delivered to customers.

Supply-chain management is the strategic, tactical, and operational decision making that optimizes supply-chain performance. The strategic level defines the supply chain network; that is, the selection of suppliers, transportation routes, manufacturing facilities, production levels, warehouses, and the like. The tactical level plans and schedules the supply chain to meet actual demand.

The operational level executes plans. Tactical- and operational-level decision-making functions are distributed across the supply chain. To optimize performance, supply-chain functions must operate in a coordinated manner.

But the dynamics of the enterprise and the market make this difficult: Materials do not arrive on time, production facilities fail, workers are ill, customers change or cancel orders, and so forth, causing deviations from the plan. In some cases, these events may be dealt with locally; that is, they lie within the scope of a single supply-chain function.

In other cases, the problem cannot be "locally contained" and modifications across many functions are required. Consequently, the supply-chain management system must coordinate the revision of plans or schedules across supply-chain functions. The ability to manage the tactical

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and operational levels of the supply chain so that the timely dissemination of information, accurate coordination of decisions, and management of actions among people and systems is achieved ultimately determines the efficient, coordinated achievement of enterprise goals.

In recent years, a new software architecture for managing the supply chain at the tactical and operational levels has emerged.

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 planning and executing their responsibilities.

An agent is an autonomous, goal-oriented software process that operates asynchronously, communicating and coordinating with other agents as needed.

This paper investigates issues and solutions in the construction of such a software architecture.

Section 2 reviews various kinds of issues and presents a list of requirements for agent-oriented architectures for the supply chain and related studies in each approach. Section 3 presents our generic model. We end with concluding remarks and future work hints in section 4.

2. Literature Review

Research in coordination of supply chains can be categorized into the following four areas:

1. Modeling of Supply Chains – the processes and functionality of supply chains must be organized and coordinated efficiently to achieve better performance. Recently, constraint network model have been studied and applied, for example, to solve problems in manufacturing industry [Barbuceanu 1998, Beck 1994, Genesereth 1994, Kalakota 1997b, Swaminathan 1998].

2. Modeling of Information Flows - which provides the communication among facilities within the supply chains, where real-time data are critical in supporting decision making. It enabled quick response and accurate data transmission. Electronic data interchange (EDI) is one of the most popular applications.

However, EDI is a closed environment for facilities within the supply chain. Internet provides a channel to support communication for both the facilities within and outside the supply chains [Barbuceanu 1998, Genesereth 1994, Kalakota 1997b].

3. Human Computer Interface (HCI) - the amount of information generated from a supply chain is overwhelming. It is important to have a good interface for users to input and retrieve data or information. Recently, many research have focused on software agents to model the behavior of the users and use the captured behavior to support design of better graphical user interface (GUI) [Barbuceanu 1998, Genesereth 1994, Kalakota 1997b, Swaminathan 1998].

4. Optimization Method – optimization is an important research area to search for better resources allocation in supply chain management. Some mathematical models have been applied to increase the performance of supply chains. But such research can be computational intensive if the number of facilities is large. Heuristic search or problem decomposition methods, random search methods, such as genetic algorithm, and negotiation methods may not guarantee global optimality, but their solutions are quicker to get and the differences from the optimal ones may be acceptable [Barbuceanu 1998, Beck 1994, Genesereth 1994, Kalakota 1997b].

Recently, several researchers have explored the intelligent agent approach to support management of supply chains. Some focused on real-time management of supply chains, while others applied rule-based mechanism and constraint relaxation approaches to model behavior of agents. Hinkkanen proposed a distributed decision support system to support real-time supply chain management [Hinkkanen 1997].

Hinkkanen modeled human decision makers as agents, who are able to adjust behavior according to the changes in the environment. For optimization of resources allocation, an auction market model was used, where resource agents and request agents submit bids and asks simultaneously. However, the optimization only focused on resources allocation within a manufacturing plant and did not consider the efficiency of delivery.

Kalakota designed an agent-based real-time system to coordinate the supply chains by modeling the system as a multi-commodity network flow problem (MCNFP) with side-constraints [Kalakota 1997b].

He employed the Primal (Benders-type) Decomposition approach to decompose the problem into a set of sub-network problems. When all the sub-network problems are solved, the overall problem also solved accordingly. Since the supply chain is very complicated, the sub-problems are also complicated and solving these problems is still not straightforward after decomposition.

Beck and Fox develops the mediated approach to coordinate the supply chains. It consists of a schema for constraint relaxation algorithms on Partial Constraint Satisfaction Problems (PCSPs) [Beck 1994].

An experiment has been conducted and the result showed that the mediated approach has better performance than Yung et al. (2000): Applying Multi Agent Technology to Supply Chain Management the negotiation approach. It also showed that the mediated algorithm using heuristic search on the aggregated constraint graph out-performed the human expert.

Barbuceanu and Fox have integrated an agent-based system with rule-based mechanism [Barbuceanu 1995].

To find the best rules that can account for the uncertainty of the environment, an associated probability is assigned to each rule and state.

In a global environment, supply chain management has to deal with globalization, proliferating product variety, organizational barriers, and quick information sharing. In response to these challenges, an appropriate model to support the supply chain management is needed. In this paper, we propose a model that integrates both intelligent agents and constraint network. Functional agents and interface agents were developed to coordinate the operation. In particular, we investigate the communication protocol among agents to support the global supply chain management.

Software agents generally exhibit characteristics that allow them to individually behave and interact with each other in such a manner that they collectively fulfill the purpose of the entire system. In their book, Shen, Norrie, and Barthes (2001) identify desirable characteristics of an agent: network-centric, communicative, semi-autonomous, reactive, deliberative, collaborative, pro-active, predictive, adaptive, flexible, persistent, mobile). Among these characteristics, four of them are largely recognized in the academic community to be essential (Wooldridge and Jennings (1994)):

Autonomy: ability to operate with some kind of control over its actions and internal state;

Reactivity: ability to sense an environment and respond in a timely fashion when changes occur;

Social: ability to communicate with each other through explicit negotiations or signal exchanges;

Pro-activity: ability to exhibit goal-directed behavior by taking initiatives.

Many agent-based approaches for the planning and control of supply chains and manufacturing activities have been proposed in the literature. For a review of these approaches, the reader is referred to Shen and Norrie (1999) and Parunak (1999). The reader is also referred to Caridi and Cavalieri (2004) who provide a recent critical analysis of multi-agent technology applied to manufacturing. Their analysis notably reveals the lack of real world applications and the low maturity level of agent-based manufacturing technology.

The reader is referred to Tharumarajah (2001) and Frayret, D'Amours, and Montreuil (2004) who analyze some of the important issues related to the design of such distributed systems, including the distribution of decisions and the coordination of manufacturing activities. Finally, concerning the use and potential role of intelligent agents in e-commerce, the reader is referred to Minghua, Jennings, and Ho-Fung Leung (2003) who thoroughly review and analyze this aspect.

Agent-based manufacturing and supply chain management approaches can be related to one of two generic classes of systems (note that agent-based systems for concurrent intelligent design are not included in this review, see Shen, Norrie, and Barthes (2001) for more details). In the mid 1980s, along with the emergence of heterarchical manufacturing systems (Vámos (1983), Hatvany (1985)), a first class of agent-based systems emerged in the academic community.

This class of systems involves agents that exhibit behaviors with rather limited decisional scope, but when combined altogether permit to address particular manufacturing problems (Table 1).

Table 1: Agent-based manufacturing systems approaches

Manufacturing problems addressed	Contributions
Flow shop manufacturing planning and scheduling	Valckenaers, Van Brussel, Wyns, Peeters, and Bongaerts (1999) Caridi and Sianesi (2000)
Job shop manufacturing control	Shaw (1987) Duffie and Piper (1986) Sycara, Roth, Sadeh, and Fox (1991) Lin and Solberg (1992) Hadavi, Hsu, Chen, and Lee (1992) Villa, Brandimarte, and Calderini (1994) Duffie and Prabhu (1994) Duffie and Prabhu (1996) Tharumarajah and Wells (1997) Liu and Sycara (1997) Kutanoglu and Wu (1999) Sousa and Ramos (1999) Parunak, Baker, and Clark (2001)
Tool management	Tsukada and Shin (1998)
Flexible manufacturing system scheduling	Kouiss, Pierreval, and Mebarki (1997)
Multi-facility production planning and coordination	Parunak (1987) Gyires and Muthuswamy (1996)
Warehouse and inventory management	Ito and Mousavi Jahan Abadi (2002)
Integrated process and operations planning	Gu, Balasubramanian, and Norrie (1997) McDonnell, Smith, Joshi, and Kumara (1999)
Capacity allocation planning	Eberts and Nof (1993) Brandolese, Brun, and Portioli-Staudacher (2000)
Schedule recovery after disruptions	Tsukada and Shin (1996)
Integrated operations planning and scheduling	Miyashita (1998) Gou, Luh, and Kyoya (1998)
Production sequencing	Wooldridge et al. (1996)

In this class of systems, referred to as agent-based manufacturing systems, the control profile of each agent (e.g., their functions/responsibilities in the overall system, their data access right, their authority and their protocols of interaction with the other components of the systems) is usually predefined.

This characteristic facilitates systems' implementation which thus consists in mapping real elements of manufacturing systems (e.g., orders, resources, products) with predefined building blocks. However, other approaches, such as Barber, Liu, Goel, and Ramaswamy (1999), propose some sort of declarative modeling framework that allow system designer to customize the control profile of each agent according to specific requirements.

During the early 1990s, along with the growing interest in supply chain management, agent-based approaches dedicated to supply chain management started to emerge in the academic community.

Fox et al. (1993) and Beck and Fox (1994) present two early applications of such systems which are referred to as agent-based supply chain management systems.

In this class of systems, agents address generally larger parts of the overall planning and control problem, such as operations or procurement planning for an entire facility or a production/distribution center. Also, each agent's profile is usually (but not necessarily) customized so as to fit within a particular planning and control framework. Some of these systems propose methods that facilitate this customization process through some sort of declarative modeling framework or customizable agent architecture that are used to specify the desired control characteristics (Fox, Barbuceanu, and Teigen (2000), Cloutier, Frayret, D'Amours, Espinasse, and Montreuil (2001), Nissen (2001), Sadeh, Hildum, and Kjenstad (2003)). In order to carry out their function, agents are also sometime geared up with advanced planning tools, some of which are based on OR technology.

Many agent-based approaches to manage supply chains have been proposed in the literature. The main problems addressed by these approaches are usually related to the synchronization of supply chain activities. However, two main streams of research can be differentiated. The first stream (Parunak (1998), Swaminathan, Smith, and Sadeh (1998), Julka, Srinivasan, and Karimi (2002)) consists in studying supply chain performance in stochastic environments through the design and simulation of supply chain models.

The focus of these approaches deals with the development of modeling and simulation environments that enable decision makers to design models of their supply chain and their decision-making processes in order to emulate as accurately as possible the behavior of supply chain members and simulate their collective dynamics. In brief, these approaches aim at analyzing the impacts on the overall performance of using particular supply chain configurations (set by the nature and parameters of supply chain models). In a context where supply chain members use complex optimization software such as APS systems to plan and synchronize their operations, it is difficult to build accurate models of such decision-making behaviors. That is why some authors have undertaken the design of simulation environments that includes such optimization tools (Lendermann etal. (2001); Lendermann, Julka, Gan, Chen, McGinnis, and McGinnis (2003); Baumgaertel and John (2003)).

The second stream of research (Fox, Barbuceanu, and Teigen (2000); Shen, Kremer, Ulieru, and Norrie (2003); Sadeh, Hildum, and Kjenstad (2003)) concerns the development of novel approaches to support supply chain members synchronize their activities. Here the focus is not placed on the use of agent-based simulation technology to study supply chain performance.

In this context, it appears that the approaches proposed within each stream of research clearly benefit from the others: the latter must be tested and evaluated dynamically, while the former should be able to simulate various approaches of coordination.

Among the approaches proposed in the second stream of research, the overall agent-based structures differ from one approach to the other. Some propose to decompose supply chains into function-oriented agents that are integrated within a global planning system. Such functions are illustrated in Table 2.

Other approaches propose to decompose supply chains into organization-based agents, usually responsible for handling the various activities of an organizational unit (e.g., a raw material supplier, a manufacturer, a distributor, a service provider, a retailer) as well as their relationships, usually client-supplier (Montreuil, Frayret, and D' Amours (2000), Qinghe, Kumar, and Shuang (2001), Gerber, Russ, and Klusch (2003), Cavalieri, Cesarotti, and Introna (2003)).

Table 2: Typical agent-based supply chain management functions

Functions	Contributions
Order acquisition/sale	Fox et al. (1993) Yung and Yang (1999) Fox, Barbuceanu, and Teigen (2000) Lou, Zhou, Chen, and Ai (2004) Kwon and Lee (2002) Lee and Lee (1999)
Mediation (i.e., coordinate other agent)	Beck and Fox (1994) Qinghe, Kumar, and Shuang (2001) Shen, Kremer, Ulieru, and Norrie (2003) Cavalieri, Cesarotti, and Introna (2003) Lou, Zhou, Chen, and Ai (2004)
Operation planning and/or scheduling	Fox et al. (1993) Fox, Barbuceanu, and Teigen (2000) Sadeh, Hildum, and Kjenstad (2003) Kwon and Lee (2002) Lee and Lee (1999)
Distribution/transportation management	Fox, Barbuceanu, and Teigen (2000)
Inventory management	Yung and Yang (1999) Lou, Zhou, Chen, and Ai (2004)
Information/knowledge management	Chen, Peng, Finin, Labrou, Cost, Chu, Sun, and Willhelm (1999) Shen, Kremer, Ulieru, and Norrie (2003)
Capacity planning	Jeong and Leon (2003)

Similarly, other differences exist between these approaches. The overall structure of an agent-based system can also take other forms. For instance, it can be holonic[4] (Gou, Luh, and Kyoya (1998), Gerber, Russ, and Klusch (2003)), heterarchic (Sadeh, Hildum, and Kjenstad (2003), Fox, Barbuceanu, and Teigen (2000), Frayret, D'Amours, Montreuil, and Cloutier (2001), Nissen (2001), Gjerdrum, Shah, and Papageorgiou (2001)), or quasi heterarchical (Qinghe, Kumar, and Shuang (2001), Shen, Kremer, Ulieru, and Norrie (2003), Cavalieri, Cesarotti, and Introna (2003), Lou, Zhou, Chen, and Ai (2004)).

In conclusion, these recent developments provide many new concepts and ideas to design solutions to support interdependent supply chain members to make their planning and control decisions so as to be collectively more efficient than if they were not coordinated.

3. The Generic Model

3.1 Agent Components

Which are the most important issues to address, to effectively build an agent-based software architecture for the supply chain? The first issue we face is deciding how supply-chain activities should be distributed across the agents.

Existing decompositions, as found in MRP (Material Resource Planning) systems, arose out of organizational constraints, legacy systems, and limitations on algorithms. For example, the distinction between master production scheduling and detailed scheduling is due primarily to algorithm limitations.

The merging of these two functions and the inclusion of some activities found in inventory management and activity planning becomes possible with the availability of more sophisticated

[4] The concept of holonic systems refers to a generic architecture that aims at describing complex systems as a recursive decomposition of systems into sub-systems, which allows systems designers to recursively capture the fundamental relationships between the whole and its parts.

planning and scheduling algorithms. With more sophisticated planning, scheduling, and coordination methods, we can build better decompositions, improving the overall quality of supply-chain management. For illustration, here is a typical agent decomposition that we use in our work:

1. Order acquisition agent. This agent is responsible for acquiring orders from customers; negotiating with customers about prices, due dates, and the like; and handling customer requests for modifying or canceling their orders. When a customer order is changed, that change is communicated to the logistics agent. When plans violate constraints imposed by the customer (such as due date violation), the order acquisition agent negotiates with the customer and the logistics agent for a feasible plan.

2. Logistics agent. This agent is responsible for coordinating the plants, suppliers, and distribution centers in the enterprise domain to achieve the best possible results in terms of the goals of the supply chain, including on-time delivery, cost minimization, and so forth. It manages the movement of products or materials across the supply chain from the supplier of raw materials to the customer of finished goods.

3. Transportation agent. This agent is responsible for the assignment and scheduling of transportation resources to satisfy interplant movement requests specified by the logistics agent. It can consider a variety of transportation assets and transportation routes in the construction of its schedules.

4. Scheduling agent. This agent is responsible for scheduling and rescheduling activities in the factory, exploring hypothetical "what-if" scenarios for potential new orders, and generating schedules that are sent to the dispatching agent for execution. It assigns resources and start times to activities that are feasible while at the same time optimizing certain criteria such as minimizing work in progress or tardiness.

It can generate a schedule from scratch or repair an existing schedule that has violated some constraints. In anticipation of domain uncertainties like machine breakdowns or material unavailability, the agent may reduce the precision of a schedule by increasing the degrees of freedom in the schedule for the dispatcher to work with. For example, it may "temporally pad" a schedule by increasing an activity's duration or "resource pad" an operation by either providing a choice of more than one resource or increasing the capacity required so that more is available.

5. Resource agent. The resource agent merges the functions of inventory management and purchasing. It dynamically manages the availability of resources so that the schedule can be executed. It estimates resource demand and determines resource order quantities. It is responsible for selecting suppliers that minimize costs and maximize delivery. This agent generates purchase orders and monitors the delivery of resources. When resources do not arrive as expected, it assists the scheduler in exploring alternatives to the schedule by generating alternative resource plans.

6. Dispatching agent. This agent performs the order release and real-time floor control functions as directed by the scheduling agent. It operates autonomously as long as the factory performs within the constraints specified by the scheduling agent. When deviations from schedule occur, the dispatching agent communicates them to the scheduling agent for repair.

Given degrees of freedom in the schedule, the dispatcher makes decisions as to what to do next. In deciding what to do next, the dispatcher must balance the cost of performing the activities, the amount of time in performing the activities, and the uncertainty of the factory floor. For example, (1) given that the scheduler specified a time interval for the start time of a task, the dispatcher has the option of either starting the task as soon as possible (just in case) or as late as possible ("just in time"); (2) given that the scheduler did not specify a particular machine for performing the task, the dispatcher may use the most "cost-effective" machine (minimize costs) or the "fastest" machine (minimize processing time). Figure 1 shows how we envisage the framework gets used.

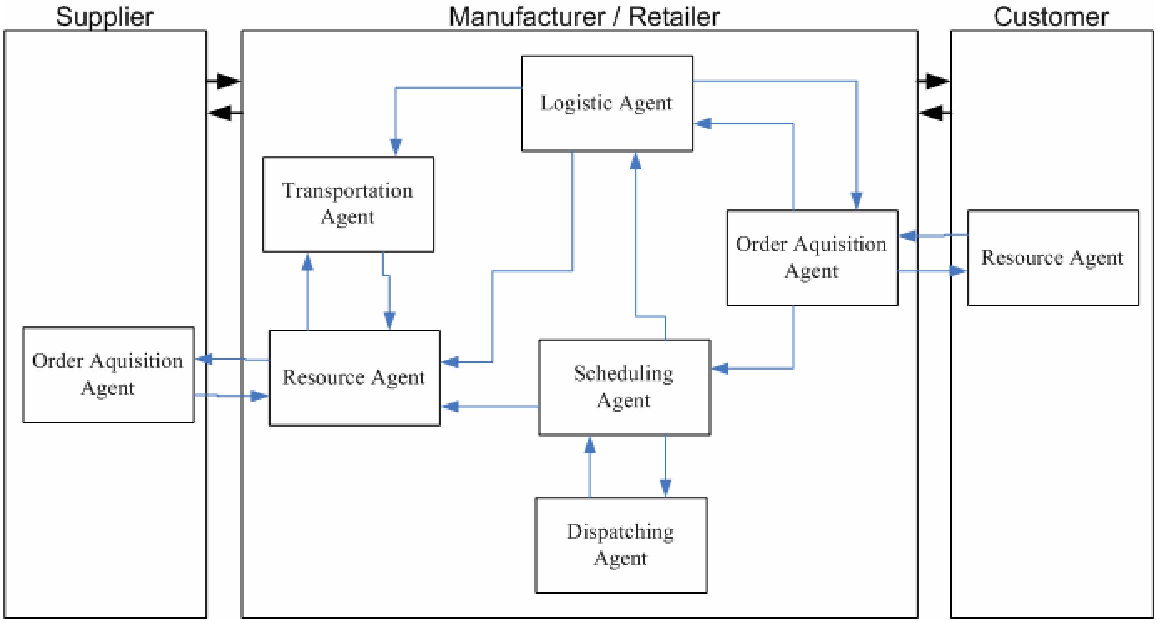

Figure 1: Modeling intra- as well as inter-organizational dynamics using the Framework

3.2. Design issues for a multi-agent supply-chain system

3.2.1. Coordination among components

The first issue is coordination among components. The dynamics of the supply chain makes coordinated behavior an important factor in its integration. To optimize supply-chain decisions, an agent cannot by itself just make a locally optimal decision but must determine the effect its decisions will have on other agents and coordinate with others to choose and execute an alternative that is optimal over the entire supply chain. The problem is exacerbated by the stochastic events generated by the flow of new objects into the supply chain. These include customer orders, new customers, shipments of raw material from suppliers, and new suppliers themselves. Modifications to customer orders (at the customer's request), resource unavailability from suppliers, and machine breakdown all drive the system away from any existing predictive schedule. In dealing with stochastic events, the agents must make optimal decisions based on complex global criteria that (1) are not completely known by any one agent and (2) may be contradictory and therefore require trade-offs.

Agents operate within organizations where humans must be recognized as privileged members. This requires knowledge of organization roles and respecting the obligations and authority incurred by the roles. Coordination and negotiation must take these issues into consideration as well, in addition to the computational cost, complexity, and accuracy of the algorithms used in optimization.

Given the dynamics of the supply chain resulting from unplanned for (stochastic) events such as transportation problems or supply problems, what nature of interaction among agents will reduce change-induced perturbations in a coordinated manner? If each agent has more than one way to respond to an event, how do they cooperate in creating a mutually acceptable solution? In other words, how do agents influence or constrain each other's problem-solving behavior?

For two or more agents to cooperate, a "cultural assumption" must exist. The cultural assumption indicates what an agent can expect in terms of another agent's behavior in a problem-solving situation. A possible cultural assumption is that agents are "constraint based problem solvers." That is, given a set of goals and constraints, they search for a solution that optimizes the goals and satisfies the constraints. Another cultural assumption could be that agents can generate more than one solution, thereby enabling the consideration of alternatives and trade-offs by a set of cooperating agents. A third cultural assumption is that agents have the ability and authority to relax a subset of constraints if the global solution is further optimized.

3.2.2. Responsiveness

The second issue is responsiveness. In a dynamic environment, the time available to respond may vary based on the event. An agent must be able to respond within the time allotted. Algorithms that can generate solutions no matter how much time is available are known as anytime algorithms. The quality of the solution of anytime algorithms usually is directly related to the time available.

3.2.3. Availability of knowledge

The third issue is the availability of knowledge encapsulated within a module. In conventional MRP systems, a module is designed to perform a specific task. The modules may contain certain knowledge (used in the performance of each task) that could be used to answer related questions. Our goal is to “open up” a module’s knowledge so that it can be used to answer questions beyond those originally intended.

In summary, the next generation supply chain management system will be all of the following:

1. Distributed. The functions of supply chain management are divided among a set of separate, asynchronous software agents.

2. Dynamic. Each agent performs its functions asynchronously as required, as opposed to in a batch or periodic mode.

3. Intelligent. Each agent is an “expert” in its function. It uses artificial intelligence and operations research problem-solving methods.

4. Integrated. Each agent is aware of and can access the functional capabilities of other agents.

5. Responsive. Each agent is able to ask for information or a decision from another agent—each agent is both a client and a server.

6. Reactive. Each agent is able to respond to events as they occur, modifying its behavior as required, as opposed to responding in a preplanned, rigid, batch approach.

7. Cooperative. Each agent can cooperate with other agents in finding a solution to a problem; that is, they do not act independently.

8. Interactive. Each agent may work with people to solve a problem.

9. Anytime. No matter how much time is available, an agent can respond to a request, but the quality of the response is proportional to the time given to respond.

10. Complete. The total functionality of the agents must span the range of functions required to manage the supply chain.

11. Reconfigurable. The supply-chain management system itself must be adaptable and support the “relevant subset” of software agents. For example, a user who wants to schedule only a plant should not be required to use or have a logistics component.

12. General. Each agent must be adaptable to as broad a set of domains as possible.

13. Adaptable. Agents need to quickly adapt to the changing needs of the human organization. For example, adding a resource or changing inventory policy should be quick and easy for the user to do.

14. Backwards compatible. Agents need to have a seamless upgrade path so that the release of new or changed features does not compromise existing integration or functionality.

4. Conclusion

We believe we have contributed in several ways to the goal of constructing models and tools enabling multi-agent systems to carry out coordinated work in real-world applications. We have contributed a model of the new type of coordination knowledge as complex, coordination enhanced plans involving interactions by communicative action.

With respect to the coordination model, previous work has investigated related state-based representations (von Martial, 1992) but has not consolidated the theoretical notions into usable language constructs, making it hard to use these ideas in applications. Formalization of mental state notions related to agency (like Cohen and Levesque, 1990) have provided semantic models that clarify a number of issues but operate under limiting assumptions that similarly make practical use and consolidation difficult. Some conversational concepts have been used by Shepherd, Mayer, and Kuchinsky (1990) and Medina-Mora et al. (1992) in the context of collaborative and workflow applications.

A number of other system capabilities mentioned in the paper are work in progress and have not played an important role in the presented applications. This is the case with role based organization models of obligation and authority among agents. As these become more mature we will integrate them in our supply chain work as well.

References

Barber, K.S., Liu, T.H., Goel, A. and Ramaswamy, S. "Flexible reasoning using sensible agent-based systems: a case study in job flow scheduling," Production Planning and Control, Vol. 10, No.7, pp. 606-615, (1999).

Barbuceanu, M., and Fox, M. S., "Integrating Communicative Action, Conversations and Decision Theory to Coordinate Agents," University of Toronto, Working Paper (1995).

Baumgaertel, H. and John, H., 2003. Combining Agent-Based Supply Net Simulation and Constraint Technology for Highly Efficient Simulation of Supply Networks Using APS Systems. In: Chick, S., Sánchez, P.J., Ferrin, D. and Morrice, D.J., (Eds.), Proceedings of the Proceedings of the 2003 Winter Simulation Conference, New Orleans, LA, USA.

Beck, J. C., and Fox, M. S., "Supply Chain Coordination via Mediated Constraint Relaxation," Proceedings of the First Canadian Workshop on Distributed Artificial Intelligence, May 1994.

Caridi, M. and Cavalieri, S. "Multi-agent systems in production planning and control: an overview," Production Planning & Control, Vol. 15, No.2, pp. 106-118, (2004).

Cavalieri, S., Cesarotti, V. and Introna, V. "A Multiagent Model for Coordinated Distribution Chain Planning," Journal of Organizational Computing and Electronic Commerce, Vol. 13, No.3&4, pp. 267-287, (2003).

Cohen, Phil, R. and Levesque, Hector, "Intention Is Choice with Commitment," Artificial Intelligence, Vol. 42, pp. 213–261 (1990).

Frayret, J.-M., D'Amours, S. and Montreuil, B. "Coordination and control in distributed and agent-based manufacturing systems," Production Planning and Control, Vol. 15, No.1, pp. 1-13, (2004).

Frayret, J.-M., D'Amours S., Rousseau A., Harvey S., "Agent-based Supply Chain Planning in the forest products industry", Research Consortium in e-Business in the Forest Products Industry Network Organization Technology Research Center (CENTOR) (2005).

Fox, M.S., Chionglo, J.F. and Barbuceanu, M. "The Integrated Supply Chain Management System," Internal Report, Department of Industrial Engineering, University of Toronto, Canada, (1993).

Genesereth, M. R., and Ketchpel, S. P., "Software Agents," Communications of the ACM, Vol. 37, No. 7, July 1994.

Gerber, A., Russ, C. and Klusch, M. "Supply web co-ordination by an agent-based trading network with integrated logistics services," Electronic Commerce Research and Applications, Vol. 2, No.2, pp. 133-146, (2003).

Gjerdrum, J., Shah, N. and Papageorgiou, L.G. "A combined optimisation and agent-based approach to supply chain modelling and performance assessment," Production Planning and Control, Vol. 12, No.1, pp. 81-88, (2001).

Gou, L., Luh, P.B. and Kyoya, Y. "Holonic manufacturing scheduling: architecture, cooperation mechanism, and implementation," Computers in Industry, Vol. 37, No.3, pp. 213-231, (1998).

Hatvany, J. "Intelligence and Cooperation in Heterarchical Manufacturing Systems," Manufacturing Systems, Proceedings of the CIRP Seminars, Vol. 14, No.1, pp. 5-10, (1985).

Hinkkanen, Kalakota, R., Saengcharoenrat, P., Stallaert, J., and Whinston, A. B., "Distributed Decision Support Systems for Real Time Supply Chain Management using Agent Technologies," Working Paper, 1997.

I. J. CHEN, A. PAULRAJ, "Understanding supply chain management: critical research and a theoretical framework", International Journal of Production Research, vol. 42, no. 1, 131–163 (2004).

Julka, N., Srinivasan, R. and Karimi, I. "Agent-based supply chain management-1: framework,"Computers & Chemical Engineering, Vol. 26, No.12, pp. 1755-1769, (2002).

Lou, P., Zhou, Z., Chen, Y.-P. and Ai, W. "Study on multi-agent-based agile supply chain management," International Journal of Advanced Manufacturing Technology, Vol. 23, No.3-4, pp. 197-203, (2004).

MARK S. FOX, MIHAI BARBUCEANU, RUNE TEIGEN (2000), "Agent-Oriented Supply-Chain Management", The International Journal of Flexible Manufacturing Systems: Kluwer Academic Publishers, Boston

Medina-Mora, Raoul, Winograd, Terry, Flores, Roberto, and Flores, Fernando, "The Action Workflow Approach to Workflow Management Technolgy," in Proceedings of Computer Supported Cooperative Work 1992, pp. 281–288, (1992).

Minghua, H., Jennings, N.R. and Ho-Fung Leung "On agent-mediated electronic commerce," IEEE Transactions on Knowledge and Data Engineering, Vol. 15, No.4, pp. 985-1003, (2003).

Nissen, M.E. "Agent-Based Supply Chain Integration," Information Technology and Management, Vol. 2, No.3, pp. 209-312, (2001).

Parunak, H.V.D. "The DASCh Experience: How to Model a Supply Chain," in: Proceedings of the 4th International Conference on Cognitive Systems-ICCS'98, New Delhi, India, (1998).

Parunak, H.V.D. "Industrial and Practical Applications of DAI," in Weiss, G. (Ed.), Multiagent Systems a Modern Approach to Distributed Artificial Intelligence, The MIT Press, Cambridge, Massachusetts, USA, (1999).

Qinghe, H., Kumar, A. and Shuang, Z. "A bidding decision model in multiagent supply chain planning," International Journal of Production Research, Vol. 39, No.15, pp. 3291-3301, (2001).

Ramakrishna Govindu, "Multi-Agent Supply Chain Modeling – A Re-Usable Component-Based Framework", Department of Industrial & Manufacturing Engineering, Wayne State University (2005).

Sadeh, N.M., Hildum, D.W. and Kjenstad, D. "Agent-based e-Supply Chain Decision Support," Journal of Organizational Computing and Electronic Commerce, Vol. 13, No.3-4, pp. 225-241, (2003).

Shen, W., Kremer, R., Ulieru, M. and Norrie, D. "A collaborative agent-based infrastructure for Internetenabled collaborative enterprises," International Journal of Production Research, Vol. 41, No.8, pp. 1621-1638, (2003).

Shepherd, Allan, Mayer, Niels, and Kuchinsky, Alex, "Strudel—An Extensible Electronic Conversation Toolkit," in Proceedings of Computer Supported Cooperative Work 1990, pp. 93–104 (1990).

Stanley K. Yung, Christopher C. Yang, Adela S. M. Lau, J. Yen, "APPLYING MULTI-AGENT TECHNOLOGY TO SUPPLY CHAIN MANAEMENT", Journal of Electronic Commerce Research, VOL. 1, NO. 4, 119-132 (2000).

Swaminathan, J. M., Smith, S. F., and Sadeh, N. M., "Modeling Supply Chain Dynamics: A Multiagent Approach," Decision Sciences, Volume 29, Number 3, summer 1998.

Tharumarajah, A. "Survey of resource allocation methods for distributed manufacturing systems,"Production Planning and Control, Vol. 12, No.1, pp. 58-68, (2001).

Vámos, T. "Cooperative Systems - An Evolutionary Perspective," IEEE Control Systems Magazine, Vol. 3, No.3, pp. 9-14, (1983).

Wooldridge, M.J. and Jennings, N.R. "Agent Theories, Architectures, and languages: A Survey," Lecture Notes in Artificial Intelligence, Vol. 890, pp. 1-39, (1994).