A Multi-Agent Architecture for a Dynamic Supply Chain Management

José Alberto R. P. Sardinha[1], Marco S. Molinaro[2], Patrick M. Paranhos[2], Pedro M. Cunha[2], Ruy L. Milidiú[2], Carlos J. P. de Lucena[2]

[1]ISRI –School of Computer Science, Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA, 15213, USA
alberto@cs.cmu.edu

[2]Computer Science Department, Pontifícia Universidade Católica – RJ (PUC-Rio)
Rua Marquês de São Vicente, 225, Prédio PLF, 13o andar, Gávea
Rio de Janeiro, RJ - Brazil - 22453-900
{milidiu,lucena}@inf.puc-rio.br

Abstract

Supply chain management (SCM) is a very challenging problem that is leveraging the e-commerce explosion. Today's supply chains are essentially static, because they rely on long-term relationships among key trading partners. Dynamic practices are vital because they offer better matches between suppliers and customers as market conditions change. This paper presents a flexible architecture for dealing with the next generation of SCM problems, based on a distributed multi-agent architecture of a dynamic supply chain. We define intelligent agent roles that tackle sub problems of a dynamic SCM. We also present an implementation of this architecture used in the international test bed for SCM solutions, the Trading Agent SCM competition, as well as some experimental results.

Introduction

The main goal of a Supply Chain Management (SCM) is to plan and coordinate activities in a supply chain [1]. These activities may have many participants, and coordination is a key aspect when efficient trading is required. Most of the supply chains in the industry are essentially static, because they rely on long-term relationships among key trading partners. The adoption of dynamic practices can offer better matches between suppliers and customers as market conditions change.

The primary goal of this work is to present a multi-agent architecture for a generic supply chain that uses a direct sales model [1], which links customers directly to a manufacturer through the Internet. We also used the design of the proposed architecture to implement an agent entry for the Trading Agent Competition (TAC SCM) [2,3] called LearnAgentsSCM. This system competed against 32 entries, and was able to classify to the quarter-finals of the 2005 competition.

The remainder of the paper is organized as follows. The second section presents the design of the multi-agent system, and the final section presents some empirical results and concluding remarks.

The SCM Multi-Agent Design

The architecture proposed uses a multi-agent approach in order to build a flexible and general design for a dynamic supply chain. Each agent can be implemented with a different AI technique, which permits a system designer to test many diverse strategies and decide the optimal combination of these techniques. The agents also use a distributed knowledge base as a key component for collaboration. Agents store results and information in the knowledge base so that other agents can use it to solve their problems. Figure 1 presents the architecture of the multi-agent system.

The main focus of the proposed design is to tackle separately important sub-problems of a supply chain: (i) procurement of components, (ii) production and delivery of finished goods, and (iii) direct sales of finished goods to customers.

The customer agents typically represent real customers and firms that are willing to buy finished goods. This agent must implement a strategy for selecting finished goods based on its preferences. This decision affects all sub-problems, but has a stronger influence in the direct sales sub-problem.

The supplier agents are responsible for selling materials/components to the manufacturers, and it directly influences the procurement sub-problem. This agent is

normally a manufacturer and could also use the design of the manufacturer proposed in figure 1.

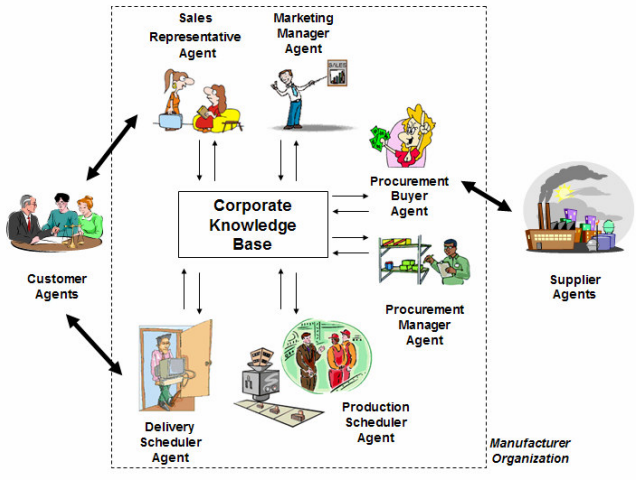

Figure 1: The Multi-Agent Architecture

The manufacturer of finished goods, also called manufacturer organization, is composed of the following agents:

- Sales Representative agent – is responsible for fulfilling customer orders. Typically, this agent has to decide the price of finished goods based on current demand and the probability of winning customer orders. In LearnAgentsSCM, these decisions are based on a stochastic programming model;
- Marketing manager agent – has to select the best customers and market segments in order to maximize the manufacturer's profitability. In LearnAgentsSCM, this agent uses a greedy strategy that chooses the most profitable Request-For-Quotes (in terms of its profit per factory cycles) and allocate them on the earliest date possible;
- Production scheduler agent and Delivery scheduler agent – have to optimize the schedule of the production and delivery of finished goods respectively. Both production and delivery are decided at the same time in LearnAgentsSCM. We reuse the model adopted in the Marketing Manager with some minor differences;
- Procurement buyer agent – negotiates components with supplier based on attributes such as price and delivery time. In LearnAgentsSCM, this agent uses a simple heuristic that selects a component with the cheapest price after receiving responses from suppliers' Request-For-Quotes;
- Procurement manager agent – decides when to buy components based on the current inventory and component demand. In LearnAgentsSCM, a multi-resolution procurement model is used in this agent.

The design of the manufacturer tackles the sub-problems mentioned above with the following agents: (i) procurement of components - Procurement buyer agent and Procurement manager agent, (ii) production and delivery of finished goods - Production scheduler agent and Delivery scheduler agent, and (iii) direct sales of finished goods to customers - Sales representative agent and Marketing manager agent.

These agents use the corporate knowledge base to exchange important information for decision making purpose. This collaboration has the ultimate goal of achieving the maximum profitability for the manufacturer organization.

Empirical Results and Concluding Remark

The 2005 TAC SCM competition had 32 entries from different research institutions around the world, and only the 24 best agents were classified for the final rounds. We implemented an entry for the 2005 TAC SCM called LearnAgentsSCM, and our system classified to the quarter-finals because it finished the preliminary round in the 16th place. Table 1 presents the final results of the Quarter-finals.

Position	Agent	Average Score
1	TacTex-05	17.78 M
2	MinneTAC	11.91 M
3	PhantAgent	7.026 M
4	Remix	6.686 M
5	LearnAgentsSCM	4.683 M
6	BonteKoe	-2.200 M

Table 1: Final scores of the 2005 Quarter-finals

The primary goal of this work is to present a multi-agent architecture for a generic supply chain that uses a direct sales model, which links customers to a manufacturer through the Internet. A multi-agent design is used in the architecture, because we believe it facilitates the development of modular entities that are distributed and reusable. The design was also used to implement an agent entry for the Trading Agent Competition. This system competed against 32 entries, and was able to classify to the quarter-finals of the 2005 competition.

References

[1] Chopra, S., and Meindl, P.. Supply Chain Management – Strategy, Planning, and Operations. Second Edition Pearson Prentice Hall, 2004.

[2] Arunachalam, R. and Sadeh, N.. The Supply Chain Trading Agent Competition. Electronic Commerce Research and Applications, Volume 4, Issue 1, Pages 66-84, Spring 2005.

[3] Collins, J., Arunachalam, R., Sadeh, N., Eriksson, J., Finne, N., Janson, S.. The Supply Chain Management Game for the 2005 Trading Agent Competition. School of Computer Science, Carnegie Mellon University, Technical Report CMU-ISRI-04-139, December 2004.