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MULTI AGENT SYSTEM FOR NEGOTIATION IN SUPPLY CHAIN MANAGEMENT

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Abstract

Supply chain management (SCM) is an emerging field that has commanded attention and support from the industrial community. Supply chain (SC) is defined as the chain linking each entity of the manufacturing and supply process from raw materials through to the end user. In order to increase supply chain effectiveness, minimize total cost, and reduce the bullwhip effect, integration and coordination of different systems and processes in the supply chain are required using information technology and effective communication and negotiation mechanism. To solve this problem, Agent technology provides the distributed environment a great promise of effective communication. The agent technology facilitates the integration of the entire supply chain as a networked system of independent echelon. In this article, a multi agent system has been developed to simulate a multi echelon supply chain. Each entity is modeled as one agent and their coordination lead to control inventories and minimize the total cost of SC by sharing information and forecasting knowledge and using negotiation mechanism. The result showed a reasonable reduction in total cost and bullwhip effect.

Keywords: supply chain management, inventory management, agent technology, negotiation mechanism.

1.0 Introduction

In an era of globalisation, key account management and, products and services designed and delivered around specific customer requirements, the way supply chains are managed distinguishes between success and failure. A supply chain is a network comprising of raw material suppliers, manufacturing plants and warehouses, distribution centres and subcontractors all engaged in the transformation of material into finished products and the transportation of those within the network and ultimately to end customers (Fig 1). Supply chain

management becomes however, increasingly complex as there is an increased reliance of businesses in outsourced services which include almost every activity from manufacturing to sales and distribution. This leads to increased uncertainty that must be addressed and complex and delicate business relationships that must be managed and maintained.

To address this complexity, businesses are exploring new forms of organization and collaboration mechanisms to work together with their suppliers and customers. Hence, there is a move away from traditional type of organisation in linear supply chains towards engaging in federal partnerships between a number of largely independent businesses which aim at virtually pooling and time-sharing resources. The aim is to introduce flexibility in managing and responding to uncertainty in market place by pooling competencies and sharing risks when responding to market needs. Such closely-knit federations can be in a dormant or a dynamic state at any time. These networks, however, regardless of state are always considered active and ready to respond. An arrangement such as this has been described as an adaptive value network (AVN) which is [9]:

> *"An arrangement where companies form a web of close relationships and work together as a system that delivers the right customized product and expected service at the right quality in a coordinated manner and are responsive and adaptable to changes in the environment."*

Among various activities in supply chain management, inventory management is the most important [12] and the effective management of supply chain inventories is perhaps the most fundamental objective of supply chain management [1].

The advent of software agent technology has triggered the development of new architectures and software for modelling and managing the supply chain [7, 9]. With this paradigm, activities in a supply chain such as procurement, planning, execution tracking etc. are represented by a software agent. Each agent acts based on its internal model of that particular activity and interacts with other agents in the network. For example an agent representing a particular warehouse can immediately provide stock availability information to another agent representing a particular customer when the latter queries stock availability before placing an order. This process takes place in real time and potentially without user interference.

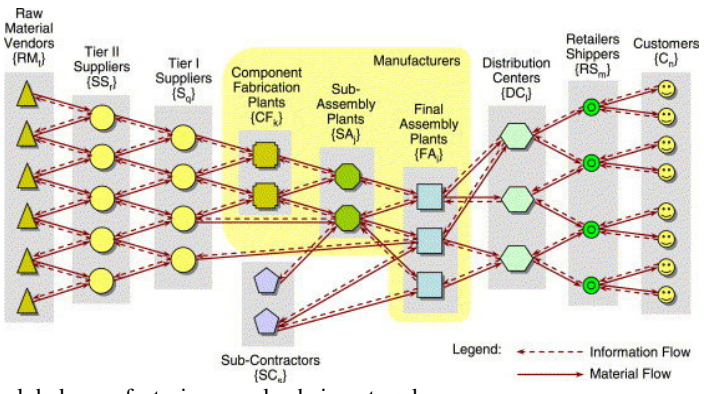

Fig. 1. Overview of a global manufacturing supply chain network

2.0 Multi Agent System for Supply Chain Management

Multi-agent system (MAS) is a fast developing information technology, where a number of intelligent agents, representing the real world parties, co-operate or compete to reach the desired objectives designed by their owners. The increasing interest in MAS is because of its ability to provide robustness and efficiency; to allow inter-operation of existing legacy systems; and to solve problems in which data, expertise, or control is distributed. The general goal of MAS is to create systems that interconnect separately developed agents, thus enabling the ensemble to function beyond the capabilities of any singular agent in the set-up [10].

The agent-based view offers a powerful repertoire of tools, techniques, and metaphors that have the potential to considerably improve the way in which people conceptualize and implement many types of 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. It is the naturalness and ease with which such a variety of applications can be characterized in terms of agents that leads researchers and developers to be so excited about the potential of the approach [4].

Multi-agent systems try to solve the entire problem by collaboration with each other. In this way, MAS can help to solve complex problems and make decisions or support humans to make decisions. Therefore, agents are especially suitable for coordination of supply chains due to the following characteristics:

1. Data, resources and control over data and resources are inherently distributed [3].

2. A supply chain is adaptive and changes over time. Agents can serve as wrappers for the supply chain management components owned by a particular supply chain entity [6].

3.0 Negotiation in Supply Chain Model

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 [2]. To coordinate different supply chain entities and solve these problems, negotiation decisions have been identified as crucial for successful global manufacturing [5].

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 [8]. In fact, negotiation is the core of many agent interactions because it is often unavoidable between different project participants with their particular tasks and domain knowledge whilst they interact to achieve their individual objective as well as the group goals. The importance of negotiation in MAS is likely to increase due to the growth of fast and inexpensive standardized communication infrastructures, which allow separately, designed agents to interact in an open and real-time environment and carry out transactions safely [11].

4.0 Multi-Agent Model Solution

The model proposed in this paper is based on beer game four echelons, but assumes unlimited entities at customer echelon and a single entity at others (Fig. 2). Three levels including supplier, distributor and retailer are allowed to have different inventory systems. Multi echelon agent based supply chain is simulated with multi agent systems. These agents are also capable of solving the problem of matching supply to demand and allocating resources dynamically in real time, by recognizing opportunities, trends and potentials, as well as carrying out negotiations and coordination. Operating in a multi agent environment, agent's plan explicitly represents interaction with other agents by exchanging messages. The agents are implemented as JAVA-thread objects on top of the JADE toolkit that satisfies the behavior as described above. This means that every agent is a separate computational process with its own internal control and a mailbox. Agents can communicate asynchronously using each other's mailboxes. The mailboxes are implemented as databases with records representing incoming messages. Besides that, all variables that represent the state of an agent are also stored in a model state database. The simulation model, which have been developed, is flexible enough to add new agents or to edit properties of existing agents to examine auction performance for different trading scenarios.

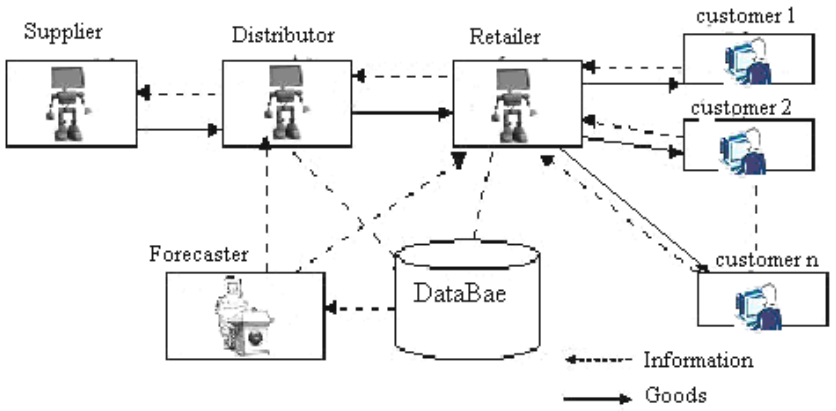

Fig. 2. abstract structure of simulated model

In this model, two types of agents are employed to respond to various types of services for the entire supply chain. One of them is a control agent and the other is a demand forecast agent. These coordinated agents have the ability to specify both static and dynamic characteristics of various supply chain entities. Customers generate random and stochastic demands at random time and only retailer give customers demand and send them goods. The same manner is employed between distributor and retailer and between supplier and distributor (Fig 2). Lead-time between echelons is deterministic and Supplier has infinite recourse. Other variables like holding and ordering cost is fixed. These assumptions are important and necessary for forecasting agent who is responsible for computing the amount of order and time to order for retailer and distributor based on Economic order quantity (EOQ).

Customer unsatisfied orders is changed to lost sale in retailer. For distributor facing a lack of inventory, retailer orders will be changed to backorder and satisfied, as goods are received form supplier. In this system, in case of lack of inventory in retailer to satisfy customers needs, retailer agent open a negotiation mechanism which help to solve this problem. By starting the negotiation mechanism retailer get new prices from customers and with the current orders and these new prices and by using a knapsack program, try to identify

which customer needs have to be satisfied. In this manner, maximum benefit can be attained for retailer (Fig 3). Generally, Fig. 4 shows the schematic model of agent-based model and demonstrates all of behaviors in each agent. We can see that there is only one database which is shared for all of agents information. forecaster agent uses these information for prediction based on new data from other agents and then send new update information for retailer and distributor.

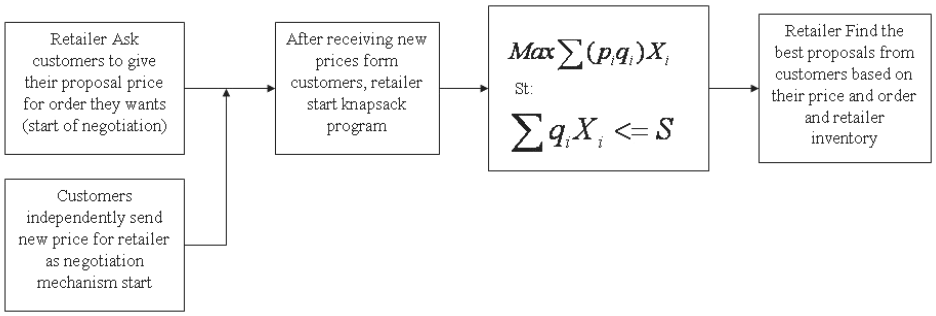

Fig. 3. Negotiation mechanism between retailer and customer

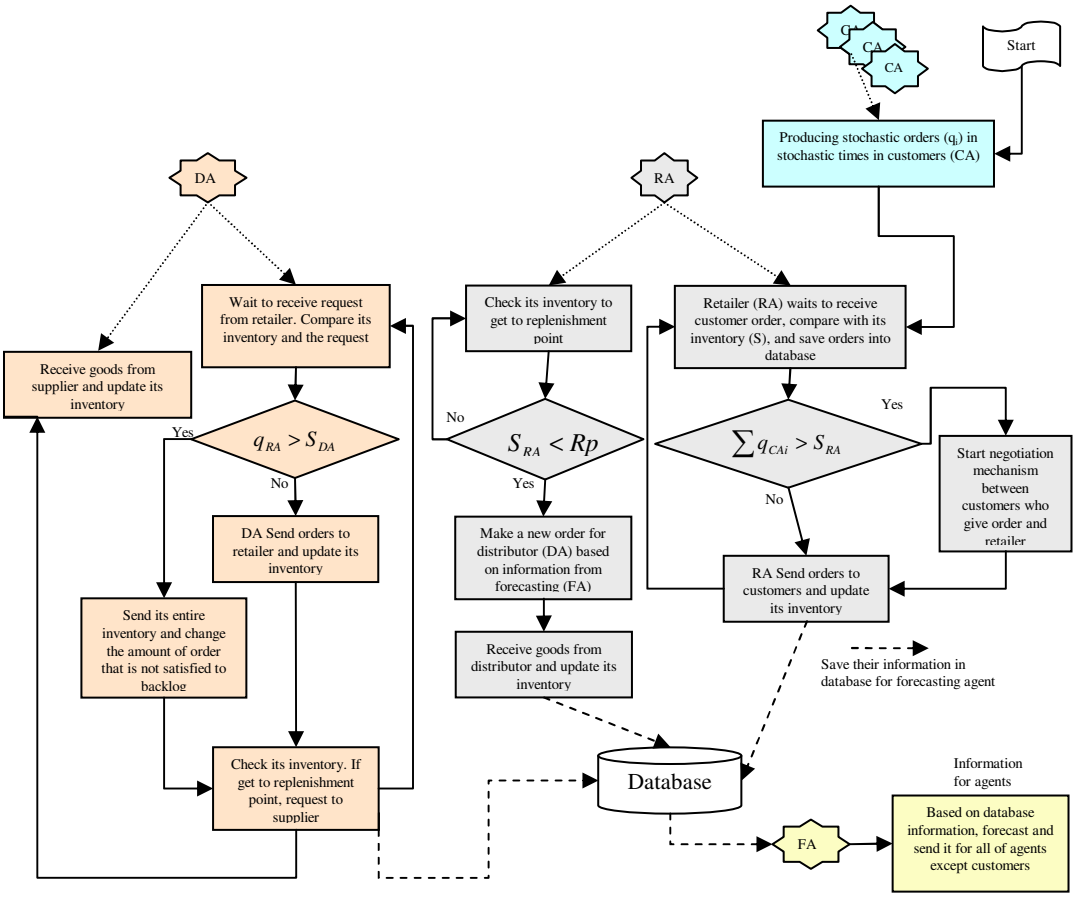

Fig. 4. schematic model of agent-based supply chain

5.0 Result and Discussion

Supply chain model as a discrete resource allocation problem under dynamic environment has been formulated, and demonstrate the applicability of the virtual market concept to this framework. The proposed algorithm facilitates sophisticated SCM under dynamic conditions. This model shows that agent technology can optimize supply chains by (a) reviewing intelligent agent's applications for supply chain optimization and (b) illustrating how a multi-agent system can optimize performance of this network.

Model benefits and saving by making use of agent-based systems for supply chain management include:

- In retailer agent, fill rate ratio (customers order satisfaction rate) calculated. All simulation runs showed 95 to 96 percent fill rate, which shows a high costumer satisfaction (figure 5).
- despite of huge and sudden demand in customs order, by agent ability, bullwhip or whiplash effect decrease in upper demand, so, total cost dose not increase so much (figure 6).

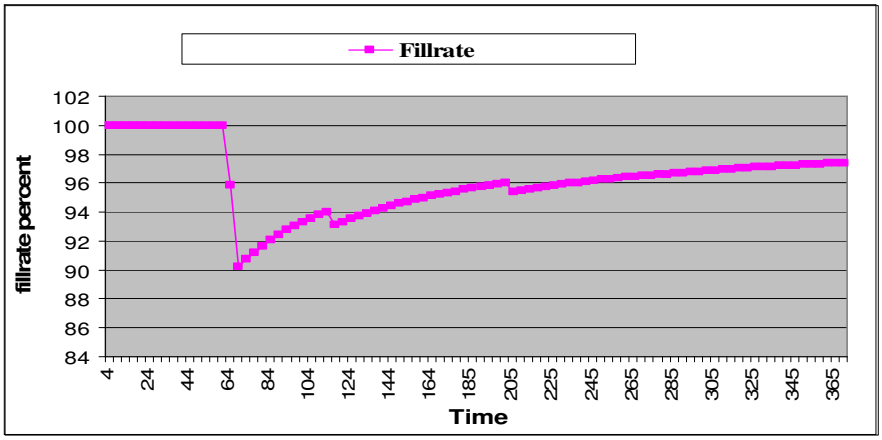

Fig. 5. Fill rate in retailer

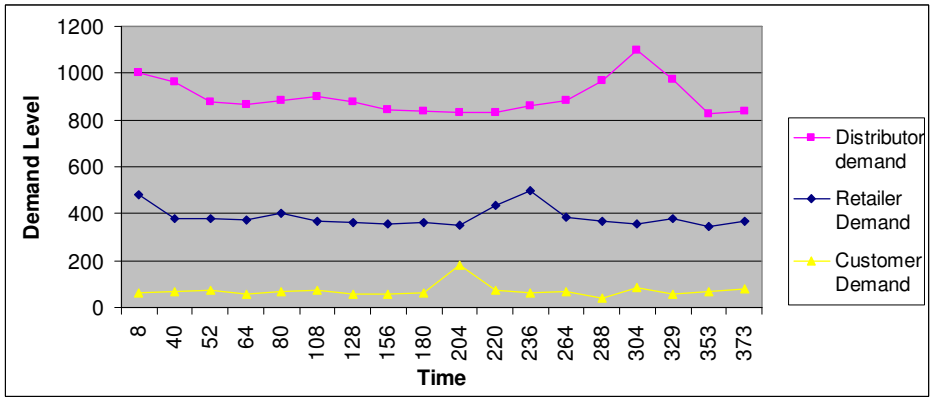

Fig. 6 Bullwhip effect in SC

6.0 Conclusion

Multi-agent system is a loosely coupled network of software agents that interact to solve problems that are beyond the individual capacities or knowledge of each problem solver. The general goal of MAS is to create systems that interconnect separately developed agents, thus enabling the ensemble to function beyond the capabilities of any singular agent in the set-up in agent model. This research can demonstrate that agent technology is suitable to solve communication concerns for a distributed environment. Multi-agent systems try to solve the entire problem by collaboration with each other and result in preferable answer for complex problems. For further works, we recommend developing this model to have multi retailer and even multi distributor and apply the auction mechanism between them.

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