Using Group Technology Concepts in the Agent-Oriented Supply Chain Management

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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. In recent years, 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 makes the system integrated and full automated. Agents need to communicate with each other to do tasks and the more communication needs the less efficiency of the system. Also as proven in manufacturing, group technology leads to reduction in communication needs in factories. In this paper using group technology concepts in agent-oriented supply chain management is regarded. This, results in reduction in communication needs between enterprise level agents and plant level agents in agent-oriented supply chain management and makes the system more distributed and scalable.

Keywords: supply chain, software agent, group technology, group analysis, organizational structure

I. 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. [FOX, 00]

To optimize performance, supply-chain functions must operate in a coordinated manner. But the dynamics of the enterprise and the market makes it 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 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. [FOX, 00].

In recent years, 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. [FOX, 00]

Intelligent agents (or intelligent software agents) are defined as being a software program that can perform specific tasks for a user and possesses a degree of intelligence that permits it to perform parts of its tasks autonomously and to interact with its environment in a useful manner [BRE, 98]. For [JEN, 98], "an intelligent agent is a computer system that is capable of flexible autonomous action in order to meet its design objectives. By flexible we mean that the system must be responsive […] proactive […], and social […]."

Machine layout in a traditional production system is mainly process (function) oriented where machines performing similar processes are grouped together. Parts requiring more than one process travel from one section of a production system to another until their operation requirements are completed. Long and uncertain throughput times are usually the major problems in such a system. Other problems include an increase in inventory holding cost, untimely product delivery, and loss of sales [GRE, 84]. Manufacturing firms have to look for better layout approaches to increase productivity.

Group Technology (GT) has been proposed as a layout approach to circumvent the above-mentioned problem. The basic idea of GT is to exploit the similarity between parts and manufacturing processes. Manufacturing firms adopting GT systems are able to reduce their material handling time, queuing time, setup time, as well as tooling requirements and total manufacturing costs (GRE, 84). To implement GT in a company, they are number of methods and one of them is Production Flow Analysis (PFA). PFA is a technique for finding the families (sets of parts) and groups (related sets of machines and other facilities) for Group Technology (BUR, 89).

PFA is a progressive technique of a succession of sub-techniques. It starts in large companies by simplifying the flow between factories or divisions, using '*company flow analysis*' (CFA). It then finds the best division of each factory into departments based on product organization and simplifies the material flow between them using ' *factory flow analysis*' (FFA). Next, it plans the division of the departments into groups with '*group analysis*' (GT). The flow of materials between the work centers in a group is then studied using ' *line analysis*' (LA). Finally '*tooling analysis*' (TA) is used to find '*tooling families*' (sets of parts which can all be made at the same set-up using tools from the same set), to plan operation 'sequencing', and to find sets of parts suitable for automation (BUR, 89).

From these sub-techniques, Group Analysis is the best match to grouping agents. The CFA and FFA are focus on the layout of the company and factories that are not considered in a virtual environment because there is no physical place. Also LA and TA are too detailed on material flow and tools that are used in manufacturing that also are not considered in virtual environment because they focus on material and tools that are physical nature. Otherwise in Group Analysis we consider the similarity of tasks that should be done by departments and this reduces the communication needs between departments. For this reason, GA is the best match sub-technique in agent-oriented supply chain management to reduce communication needs between agents in the system by grouping them.

In this paper we want to use group technology concepts in order to reduce communication needs in agent-oriented supply chain management. In second part we describe the system architecture of the agent-oriented supply chain management. In third part, the information agent – an agent that is responsible to communicate between agents in the system – is described. In the forth part, a Group Analysis algorithm to grouping agents in the multi-agent systems is introduced. In the fifth part we propose a new organizational structure for agent-oriented supply chain. Finally the sixth part is conclusion about this paper.

II. SYSTEM ARCHITECTURE

System architecture refers to the components of the system and their linkages and communication structure. Like a real enterprise, agent base systems have architecture. Architecture of agent-based system is diverse according to the role of each agent or interrelationship among agents and the nature of systems duties. Let us look at the system architecture of agent oriented supply chain management.

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 (FOX, 00). Agent Oriented Supply Chain Management addresses the coordination problems at the tactical and operational levels.

There are several types of agents in the system. According to (FOX, 00)they are:

- *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.
- *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.
- *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.
- *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.

• *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.

• *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).

• *Plant Management.* This agent distributes work among plant level agents, based on the orders received from logistics. It also conducts negotiations when orders can not be fulfilled as requested or when plant level agents can not reach an understanding. (BAR,1995)

These agents need to communicate with each other to do their tasks and solve the problems. So the system needs a communication mechanism. There are several communication mechanisms in agent base systems such as facilitator approach; broker approach, matchmaker approach, and etc. for more study about these mechanisms refer to (SHE, 2001). In agent oriented supply chain, matchmaker mechanism is used.

According to (DEC, 96), "the process of matchmaking allows one agent with some objective to learn the name of another agent that could take on that objective" and "a matchmaker (also called Information Agent) is an agent that knows the names of many agents and their corresponding capabilities." So, the main functionality of this agent is to establish links between client agent (also called requester, user, etc.) and service agents (also called providers. Servers, etc.). After such links are established, the client agents may communicate directly with the service agents without further contacting the matchmakers. We will talk more about Information agent in next part.

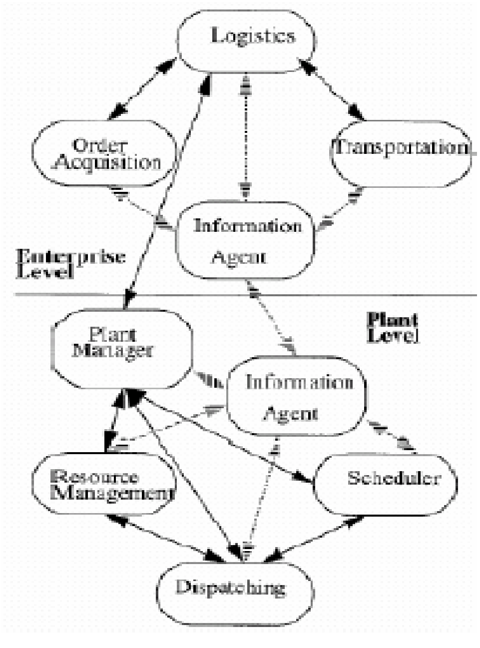

Fig.1. System Architecture

As you see in figure --- a supply chain has four agents at enterprise level (Information Agent, Logistics, Order Acquisition and Transportation) and five at each plant (Information Agent, Plant Management, Resource Management, Dispatching and Scheduling agents), so a typical system can have 40-50 agents (SHE 2001)

As you see the information agent is like an information system in the system. And agents can communicate through this agent type. Let take a closer look to it.

III. INFORMATION AGENT

Information Agent is a kind of middle agents. [DEC, 97] put forward the concept of middle agents, which are used to "support the flow of information in electronic commerce, assisting in locating and connecting the ultimate information provider with the ultimate information requester."

So we can identify two types of agents in the system, Information Agents and functional agents. Functional agents register their capabilities and needs with an

Information Agent. Information Agents receive information from functional agents, reason about its relevance to other agents and distribute it to those agents for which they consider it relevant, and in the form that is easiest to understand.

If distributed information ever becomes inconsistent, the Information Agent mediator will alert all receivers. If functional agents supply contradictory information, the mediator will apply strategies for solving the conflict and reinstall consistency. Communication takes place using the KQML/KIF. (BAR 1995)

Information Agents are agentified knowledge and data management systems that allow other agents from the computerized organization to be selectively aware of relevant information by providing communication and information services related to (BAR 1994):

- Persistent storage of information to be shared among the multiple functional agents.
- Deductive capabilities allowing new information to be inferred from existing information and domain knowledge.
- Automatic, content-based routing and distribution of information to the agents that need it.
- Automatic retrieval, processing and integration of information that is relevant to agents.
- Checking and maintaining various forms of consistency of the information. We address terminological consistency, assertional consistency and temporal consistency.
- Supporting personal reasoning.
- Providing change management services.

The Information Agent is composed of two components (figure 2): an agent program and knowledge management (BAR 1994). The Agent Program is responsible for social interaction function and the knowledge Management System has the goal of providing the common representational and reasoning substrate on top of which the other components and services of the Information Agent are built.

For more study about Information Agent you can refer to (BAR, 94).

IV. IMPLEMENTING GROUP TECHNOLOGY IN AGENT ORIENTED SUPPLY CHAIN MANAGEMENT

Group Technology had great impact to manufacturing organizations and reduced the communication needs and transportation of materials in factory floor. Group technology arranges the company by products. But how it can be in Agent Base Supply Chain Management. Our purpose is to recognize the domains of agents that are relevant to specific task. For this, we use the Group

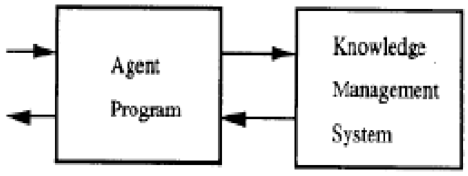

Figure 2. Architecture of the Information Agent

Analysis algorithm of (BUR, 89) adapted for Group Analysis in agent base systems.

A. *Group Analysis algorithm for agent base systems*

In this algorithm we have two items that should be considered: Task and Domain. Tasks are duties that should be done about each order that receives to the system and the domains are set of agents that do the tasks in a plant level. Therefore each domain contains five agents (plant management agent, dispatching agent, scheduler agent, resource management agent and one information agent). This algorithm has 11 steps as follow:

1. *Finding the value of F and N for each Domain*

At first we should determine the value of F an N for each Domain that N is the total number of domains that are similar to this type of domain and perform similar tasks and F is the total number of tasks that this Domain can perform.

2. *Determining the SICG code for each domain*

SICG code is determined by algorithm presented in figure 3.

a. Special (S) category: there is only one of each of these S types Domains (N=1). These domains perform special operations that cannot be transferred to other Domains. This is too expensive and difficult to transfer operation of these domains to another domain.

b. Intermediate (I) category: this domains are similar to S class Domains but there is more than one of each domain type of this category (N>1)

c. Common (C) category: there is more than one of each of these C type Domains (N>1) and these domains are used for operation on several tasks (F is large) and usually used in several groups.

d. General (G) category: Domains of this category are used for operations on large number of tasks (F is large) and it is difficult to include them just in one group and they can be used as a service center for other groups.

3. *Preparing Special List (SL) and find modules*

Each module consists of a set of tasks, together with a set of domains used to perform them. Each module is based on the key domain. The key domains are found in turn from specially list that we consider as Special List (SL). This lists all the S, I, C and G category domains one after the other in that sequence. Inside each category the domains are listed in ascending value of F (SL sequence). The key modules are selected in sequence from the SL to form modules, starting with the S class module, which has the lowest value of F. each module includes:

a. A list of the domains used, to tasks be done

b. A matrix showing the task numbers and the domains that are used, to do tasks.

4. *Preparing module summery*

Module summery is the summery of all of the modules generated in the base of key domains that ordered by SL sequence.

5. Preparing Module Cross-References

It is about distribution of significant attributes between Modules such as participation of modules in performing a specific task. This can be useful for integration of modules and forming groups in the next step.

6. *Determining the number and the size of groups*

We should determine the number and the size (number of tasks and domains included) of groups in this stage. The size of a group is in the relation with the complexity of the order that should be satisfied. In general very complex orders, forms a larger group than simple orders. There is no absolute rule about group size and it is up to expert's idea.

7. Plan the groups and select nuclei:

The factors, which bring a pair of modules together when forming groups and families, include various combinations of following:

a. They use many of the same Domains.
b. They both use the same S type Domain
c. Their tasks are similar or same
d. Their tasks all require same supporting process.

8. Group selection (systematic approach):

a. Find obvious groups base on S and I class modules, select modules for nuclei
b. Select simplest groups based on C class modules, select nuclei.
c. Search for additional groups based on remained S class modules.

9. Add free modules to groups:

If a module will only fit in one group, add it to that group. If it will fit in more than one group, add it to the group with smaller number of domains.

10. Print out final group summery:

In this stage we should record all of the generated groups.

11. Allocate Domains to groups:

Domains are allocated to the groups in the base of number of tasks in the group, which this domain can perform.

For more detail about group analysis algorithm you can refer to (BUR,89).

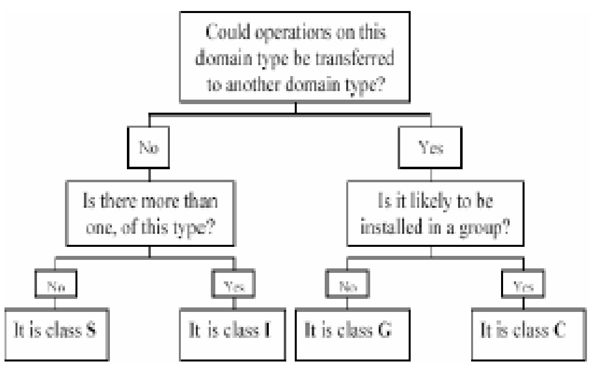

Fig.3. Identifying SIGC code

V. PROPOSED ORGANIZATIONAL STRUCTURE

At the end of group analysis algorithm, we have identified groups, domains included in each group, SICG code of each domain, tasks that can be done in each group, etc. So we can arrange a new architecture in the base of new groups. As you now the current organizational structure of Agent Oriented Supply Chain Management is as figure 4. In this structure coordination between the plants that are contributed in specific task, is done at enterprise level.

Before introducing the proposed organizational structure let us to introduce a new agent type in the system that is *group agent*. Group agents are responsible for communication between domains in each group level that have identified by group analysis algorithm. Internal components of a group agent is like Information Agent but its knowledge management module contains knowledge about regarded group (group that this agent is responsible about) such as domains (plants) that included in this group, tasks that can be done in this group, work load of the group and so on.

In proposed organizational structure we have several groups in plant level that each group is responsible about a set of orders. In, group technology in manufacturing companies we arrange company by products. In Agent Oriented Supply Chain we arrange the system by orders that can be satisfied by the system. As you can see in figure 5 there is a Group Agent (GA) above each group that coordinates the domains included in each group.

When a new order received to enterprise level of system (by order acquisition agent) the Information Agent of enterprise level recognize the group that this order is related to, and send a request to the group agent of that group. Then the group agent coordinates all domains that are included in the group until the order be satisfied or be rejected. Information agent in enterprise level just has knowledge about groups and their skills and duties and also has knowledge about enterprise level agents. But it hasn't knowledge about plant and this knowledge is delegated to group agents.

As you see in figure 5 there are some of domains that are member of different groups. For example D4 and D5 are members of group 1 and group 2. These domains are G class domains according to SICG code that described in group analysis algorithm.

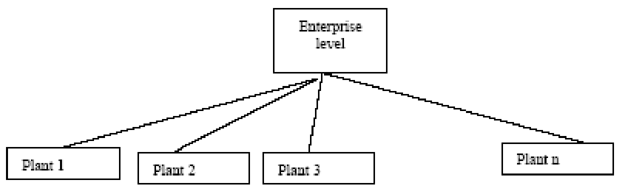

Figure 4: organizational structure

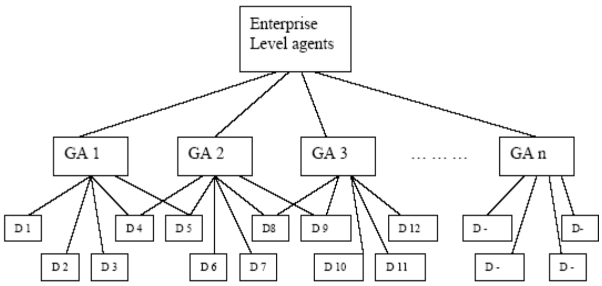

Figure 5: proposed organizational structure

Lets look at advantages of this proposed organizational structure. When we determine our structure like this, the communications delegated to the operational level of the supply chain. This lead to reduction in communication needs in enterprise level.

Also in operational level communications will be reduced because only the domains that are relevant in an order are considered to satisfying an order and irrelevant domains are not considered because they are not in the group and they are blocked to send the message to them. This new structure also has these advantages over Agent Oriented Supply Chain Management:

- *This make the system distributed:* the functionality of the system is distributed over the autonomous groups of agents.
- *This may lead to better learning about orders*. Because each group agent is responsible about specific order, the learning is easier for this agent. Perhaps it needs to have a learning module if we wish it to do so.

Ability to manage the huge systems. When the number of domains and agents increases, current structure may not be efficient because there will be high workload on enterprise level and information agent (in particular). By this proposed structure, the workload of enterprise level will decrease because of delegation to group agents.

VI. CONCLUSION

In this paper we have introduced the concept of Group Technology for Agent Oriented Supply Chain Management. It leads to the new organizational structure of the system. This new organizational structure is according to shaping groups that each group is about specific order in the system. By this our purpose is to decrease communicational needs and workload in the enterprise level of the system. When the workload of enterprise level be decreased, agents in this level are able to manage more group of agents in the system and this make it possible to expand the systems capabilities and domain of work.

Study about learning modules in group agents may be the topic of future work.

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