MOBILE AGENT BASED SUPPLY CHAIN MODELLING WITH NEURAL NETWORK CONTROLLED SERVICES

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ABSTRACT

Supply Chain refers to any system of consisting of multiple entities (companies or business units within an enterprises), that depend on each other in some way in conducting their businesses. In this paper, we intend to introduce a new approach, based on mobile agents, which is capable in providing near-optimal adaptive business and knowledge management strategies to help managers for reducing mental efforts as well as search costs. Our mobile agent based system uses the publish/subscribe communication mechanism, therefore, customers and suppliers can dynamically connect and disconnect to the system at any time. System uses mobile agents as a mediator between customers and suppliers, with a two-leveled mobile agent structure and some design details of the procurement process that is a part of an ongoing research at Turkish Air Force Academy, based on neural network approach of a supply chain management system is represented and implemented.

1. INTRODUCTION

A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers. Supply chains exist in both service and manufacturing organizations. Realistic supply chains have multiple end products with shared components, facilities and capacities.

Traditionally, marketing, distribution, planning, manufacturing, and purchasing along the supply chain operated independently. These departments have their own objectives and these are often conflicting. Marketing’s objective of high customer service and maximum sales conflicts with manufacturing and distribution goals. Many manufacturing operations are designed to maximize throughput and lower costs with little consideration for the impact on inventory levels and distribution capabilities. Purchasing contracts are often negotiated with very little information beyond historical buying patterns. Thus, there is a need for a mechanism through which these different functions can be integrated. Supply chain management is a strategy through which such an integration can be achieved.

Through the past decades we have seen an increasing rate of globalization of the economy and thereby also of supply chains. Products are no longer produced and consumed within the same geographical area. Even the different parts of a product may, and often do, come from all over the world. This creates longer and more complex supply chains, and therefore it also changes the requirements within supply chain management The rapid development within the information and software engineering gives unprecedented opportunities for integration and coordination. Many of the advances in the control and management of supply chains are driven by advancing computer technology. This again affects the effectiveness of computer systems employed in the supply chain.

The competitive marketplace of the 21st century demands robust and extended enterprise management solutions/ initiatives that integrate product, process and information flows within and across organizational boundaries. The challenge is to effectively use electronic data interchange to identify, communicate and continuously improve internal and extended enterprise processes. The modern computer networks have the ability to rapidly distribute information to all concerned entities of an enterprise. The networks also present an infrastructure for coordination of planning and operational process, not only within organizations, but also among them. The computers of the various corporations, located throughout the world, will communicate with each other to determine the availability of components, to place and confirm orders, and to negotiate delivery timescales [1].

Software agents help automating a variety of tasks including those involved in buying and selling products over the Internet. Agent activities in terms of products required and supplied are defined so as to reduce an agent's decision problem to evaluate the tradeoffs of acquiring different products. Such agents are designed to reduce a user's information overload or search costs. The difference between such systems and conventional programs is that they are domain-specific, continuously running and autonomous.

We are interested in coordination and control mechanisms of mobile-agent based supply chains for knowledge management with a formal approach by using and developing neural network based analytical tools.

The remainder of the paper is organized as follows. In Section 2, we focus on coordination mechanism in supply chains. In Section 3, we discuss mobile-agent based customer-supplier system and its subsystems such as Control/Optimize Service. In Section 4, system performance is evaluated and Section 5 ends the paper with some concluding remarks and future works.

2. COORDINATION MECHANISM IN SUPPLY CHAINS

Applications of multi-agent systems in manufacturing and supply chain management are not new. In intelligent manufacturing, agents have been used in different functional areas such as: configuration design of manufacturing products [2], coordination in multi-agent systems for agile manufacturing [3], scheduling and controlling of manufacturing operations [4, 5], vehicle routing, and enterprise modeling [6], and determining production sequences [7]. Sikora and Show provide a multi-agent framework for the coordination and integration of information systems [8]. Gilman et al. integrates the design and manufacturing in a virtual enterprise rules, intelligent agents, STEP and workflow [9]. Shen and Norrie provide a survey of agent-based systems for intelligent manufacturing.

In supply chain management, Yung and Yang propose the integration of multi-agent technology and constraint network for solving the supply chain management problem [10]. Yan, Yen and Bui develop a multi-agent based negotiation support system for distributed electric power transmission cost allocation based on the network flow model [11]. However, the coordination mechanism by using mobile agents has neither been addressed in agent-based manufacturing nor in agent-based supply chains. This is the focus of our research. We also incorporated neural network approach in different vendor selection process in order to help decision making process.

3. SYSTEM DESIGN

We designed a procurement process of the supply chain in a large-scale and dynamic environment, which there can be any number of customers and suppliers at any time. Suppliers can connect, register or unregister to the system at any time, thus preserving the dynamic structure of the system. Therefore, the architecture that we propose is based on the publish/subscribe paradigm which supports many-to-many interaction of loosely coupled entities as depicted in Figure 1. In this model, customers do not know either the number of the suppliers or the addresses of them. A customer sends its request to the Manager, by means of mobile agents, and then Manager dispatches mobile agents to the selected suppliers. We define the set of services that need to collaborate with the publish/subscribe infrastructure to address the dynamics of mobile environments.

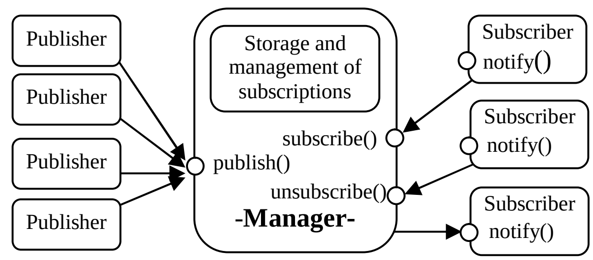

Figure 1. Publish/Subscribe model

Our work consists of a framework for a large-scale supply chain system that uses the publish/subscribe paradigm and exploits mobile agent technology extensively. It not only supports activities of customers and suppliers, but also facilitates parallel computation by running mobile agents on suppliers concurrently.

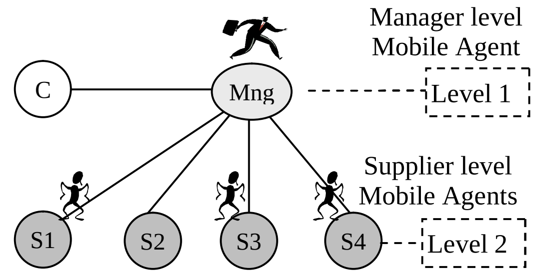

Figure 2. A Two-Leveled Mobile Agent Model

The system uses mobile agents as mediator between customers and suppliers. Mobile agents belong to two different levels of execution (explained with details in [12]) and responsibilities, as shown in Figure 2, Manager level Mobile Agent (MMA) and Supplier level Mobile Agents (SMA). A MMA is created by a Customer Agent and is sent to the Manager. This MMA creates SMAs and sends them to suppliers in order to search their databases, to select among products, and to negotiate with the supplier, if necessary. The system does not include only a single mobile agent that visits every supplier one by one. Instead, we send a replication of the mobile agent to each of the suppliers concurrently, and thus make use of parallel processing. This model of parallel computation is especially important as more suppliers can be searched in a shorter time to provide customers with better choices in their decision-making.

In many of supply chain systems and electronic commerce systems, a customer (or the system) has a fixed number of suppliers, which are initialized to the system at start up. When a new supplier is to be added, it has to be registered manually by supplying its address and the necessary parameters. In a large-scale and dynamic environment, there can be a varying number of customers and suppliers at any time. In a dynamically changing electronic marketplace, a system should have the ability to adapt itself to this dynamic world. To meet this requirement, we have designed an architecture that utilizes the publish/subscribe paradigm for registration and dispatching operations, to increase efficiency and effectiveness of the procurement process in terms of costs, quality, performance, and time for both customers and suppliers.

A user who wants to buy a product creates an agent, gives it some strategic direction, and sends it off into a centralized agent marketplace. Mobile agents of the system proactively visit suppliers and negotiate with them on behalf of their owners. Each agent's goal is to complete an acceptable deal, subject to a set of user-specified constraints such as a desired price, lowest acceptable price, and a date by which to complete the transaction.

Using our approach, supply chain models are composed from software components that represent types of static supply chain agents (like customer agent, controller agent and supplier agent) and mobile supply chain agents (like manager level mobile agent and supplier level mobile agent). Agent descriptions provide an ability to specify both static and dynamic characteristics of various supply chain entities. Each agent is specialized according to its intended role in the supply chain

The system has an extensible architecture, as depicted in Figure 3, and provides all the services, which are essential to agent-based commercial activities. Our procurement process system of the supply chain involves three main actors: *Customers* are looking for purchase services from suppliers. *Suppliers* or sellers offer the services or products and a *Control/Optimize Service* facilitates selection of the suppliers and communication between customers and these suppliers.

3.1 Customer Subsytem

To request a purchase order from the system, a customer has to initialize a Customer Subsystem on its machine. Customers have to know the address (URL) of the manager agent that they will connect, just like the URLs of well known web sites (i.e. Yahoo!, Alta Vista or Excite).

The Customer Subsystem consists of four main

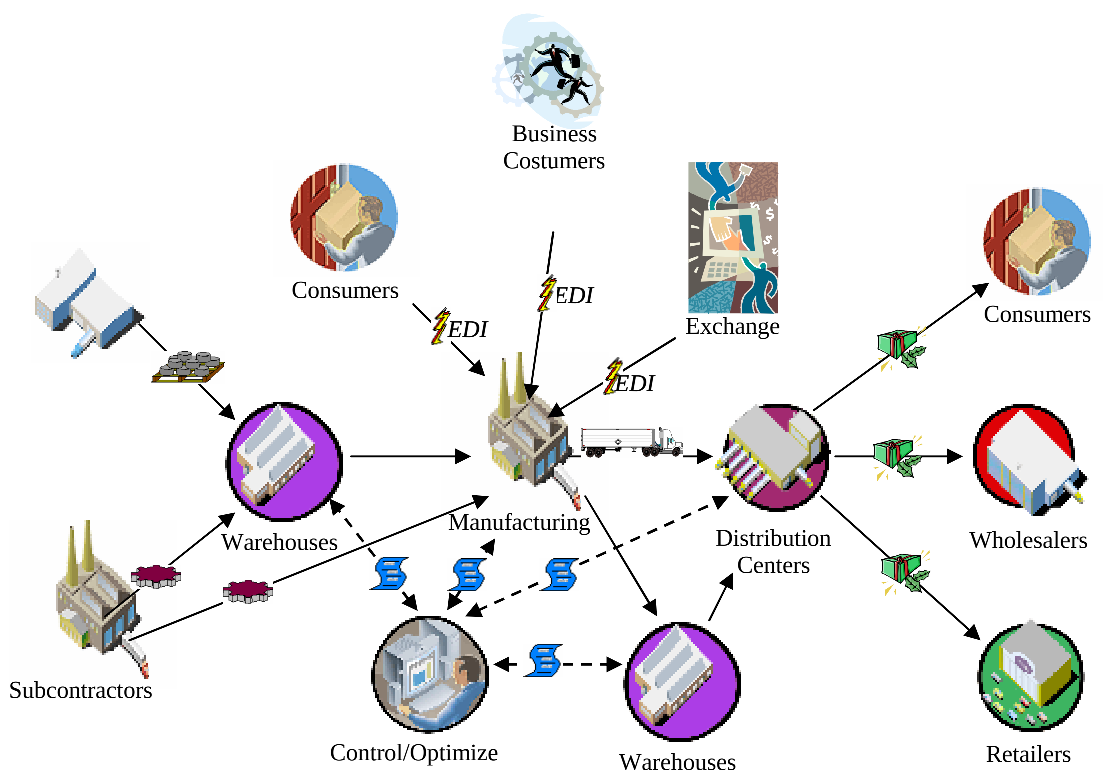

Figure 3. Supply Chain Management system

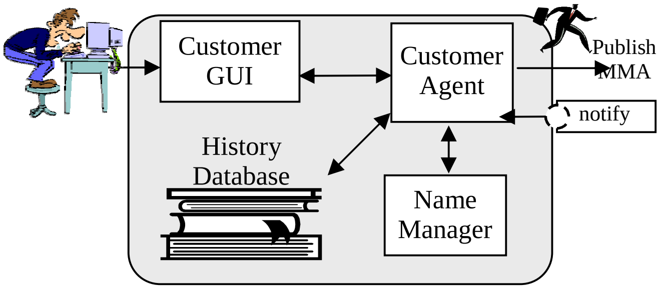

Figure 4. Customer Subsystem Architecture

components as shown in Figure 4.

a. History Database contains result reports of past procurements and a human user can inquire this information via GUI and can change some knowledge about suppliers at any time.

b. Graphical User Interface (GUI) is used for interaction (i.e. getting a new procurement process from a customer, or searching from the History Database) with human users.

c. Customer Agent acts on behalf of the user.

d. Name Manager is used for the naming of the mobile agents as a unique identifier in the system.

As several transaction scenarios are possible, allowing users to generate Manager level Mobile Agents with different behavioral characteristics increases the flexibility of the system. A human user interacts with the Customer Agent via the Customer GUI module. In the beginning of a transaction, the user supplies the necessary information. Orders contain information on: types of products that are being ordered, the number of products that are required, the destination where the product has to be shipped, and the due date of the order. The Customer GUI allows users to control and monitor the progress of transactions, and to query past transactions from the History Database.

Customer Agent is the main process of the Customer Subsystem. Customer Agent is a stationary agent that is created during the initialization step of the subsystem. It is responsible for offering an interface to end users for inputting query tasks and communicates with the Manager level Mobile Agents it creates to accomplish its task.

Customer Agent is created with the basic capability to perform routine and simple tasks. Tasks that are more complicated may involve human instructions but once instructed, the agents cache them for future use. This can be achieved by using learning methodologies on Customer Agent. The main function of a customer agent is to search for product information and to perform goods or services acquisition. When a customer agent receives a purchase request from a user, it creates a Mobile Agent to search for product information and to perform goods or services acquisition in the system. Customer Agent specifies the criteria for the acquisition of the product and dispatches the MMA to the manager. When this MMA reaches the best deal, it sends a result report to Customer Agent and this information is added to the History Database.

3.2 Supplier Subsystem

As it is known, the supply chain is a complex process and even a simple procurement process on a supplier can be complicated by supplying the sub-part of the product from other tier II supplier or from raw material vendors. In this system, we assume that the suppliers can make these products without purchase of any components and as a result, the supply

A supplier has to initialize a Supplier Subsystem on its machine to join the system. When a supplier system is created for the first time, it subscribes to the system providing its address and the names of its products. If a supplier starts or ends delivering a product, it again subscribes or unsubscribes its products respectively.

Every supplier agent has to know the address of the Manager so that it can make a connection. Supplier agent subscribes to the manager by sending its product definitions and waits for customers to make requests for his products.

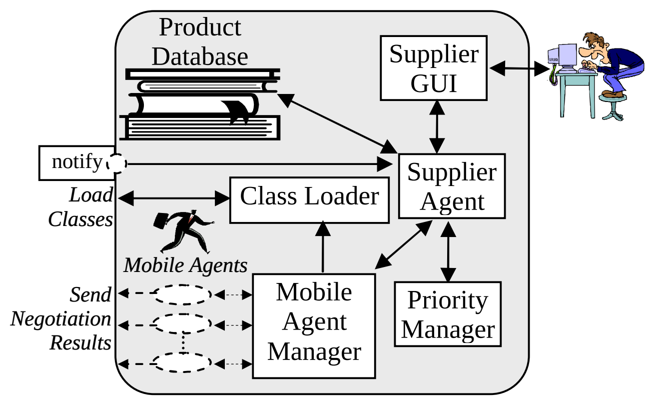

Figure 5. Supplier Subsystem Architecture

The Supplier Subsystem includes six main components as shown in Figure 5.

a. Product Database contains the services and product details of the supplier.

b. Graphical User Interface (GUI) which is used for interaction (i.e. inquiring about past and current transactions from the agent, or a user may also specify selling strategies through this module) with human users.

c. Mobile Agent Manager controls and coordinates the incoming SMAs.

d. Priority Manager checks the waiting requests (SMA) and selects the one with highest priority.

e. Class Loader downloads the necessary classes from the Manager.

f. Supplier Agent acts on behalf of the user.

Most of the software systems are built around simple control mechanisms for processing events such as first in, first out (FIFO) queues. However, supply chain interactions typically involve more sophisticated control mechanisms. For example, when an important order comes in, it may have to be processed first, ahead of other orders.

Performance measures of the agent, as well as the other important commitments (like cost, delivery time etc.) influences priority of the agent. These priorities determine the sequence in which incoming requested are processed. For example, the supplier agent may prioritize customers according to an A-B-C classification, thereby sequencing the "A" customer order before others when there is more than one outstanding order. If the priority of all the orders are the same, then it is FIFO [first in first out].

Supplier Agent is also a stationary agent, which is responsible for offering an interface to end users to enter information, control the operations, and input query tasks. Supplier Agent processes purchase orders from customer agents and decides how to execute transactions according to selling strategies specified by the user. Since organizations differ in the products they sell, a supplier agent should be customized before it is placed online.

3.3 Control/Optimize Service

The Control/Optimize Service plays the most important role in our Supply Chain system. It is a logically (also physically in our system) centralized party which mediates between customers and suppliers in an electronic marketplace. The main component of the Control/Optimize Service is the "manager". Manager is useful when a supply chain system has a number of customers and suppliers, when the search cost is relatively high or when trust services are necessary. The inner structure of Manager is shown in Figure 6.

The client-server paradigm is often not sufficient to solve satisfactorily the problems that may arise during the system life cycle. Often one wants to add a supplier or a customer to the supply chain system after its design-time. In the system that we present, the manager implements the publish/subscribe paradigm in which purchase events are published and made available to the supplier components of the system through notifications.

There are two main manager modules in the system; KnowledgeBase Manager and Queue Manager modules. KnowledgeBase Manager manipulates two important databases.

Knowledge Base keeps statistical information about suppliers, customers and products in the system, according to message transactions between customer and supplier agents.

Subscription Base keeps simple information, such as names of services or products, which are delivered by suppliers. It also contains supplier id and password pairs for authorization of suppliers.

The Queue Manager has access to five major queues in the Manager. These queues are used for execution of manager modules concurrently:

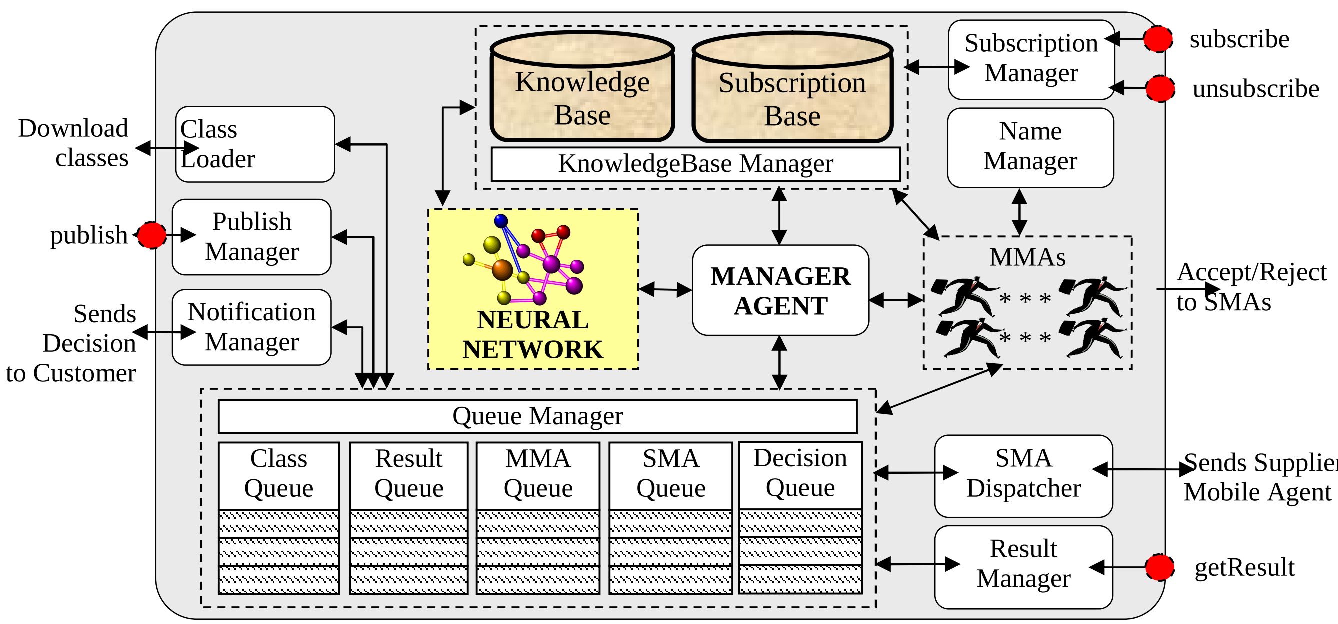

Figure 6. Inner structure of the Manager

a. *Class Queue* contains the names and addresses of the classes that are required to be downloaded by the MMAs.

b. *MMA Queue* contains the serialized form of incoming MMAs from Customers.

c. *SMA Queue* contains the serialized form of outgoing SMAs to Suppliers

d. *Result Queue* contains incoming results from the SMAs.

e. *Decision Queue* contains the decision data of a MMA, that is to be sent to Customer Agent.

In these queues, each agent selects incoming messages in the system according to first come, first served (FCFS) model. There is a global list of incoming messages for all queues, sorted in terms of time of activation, and the agent that has the earliest message is processed next.

The manager consists of eight manager modules, which run in parallel in the system. These are Class Loader, Publish Manager, Notification Manager, Subscription Manager, SMA Dispatcher, Result Manager, Name Manager and Manager Agent. The tasks of these managers and the execution flow of a procurement process in the Manager is as follows:

a. Subscription Manager gets subscription messages from suppliers via *subscribe* and *unsubscribe* methods, verifies their supplier_id and passwords with the Subscription Base, and continues with the necessary actions.

b. Publish Manager receives the serialized forms of incoming MMAs from the Customer Agent via publish method and adds them to the MMA Queue. It also gets names and addresses of the necessary class via the same method and adds them to the Class Queue.

c. Class Loader downloads classes in the Class Queue from Customer Subsystem through a call to the "downloadClass" method of the Customer Agent.

d. Name Manager is used for naming operations of the SMAs

e. Manager Agent creates and activates a thread for each MMA in the MMA Queue.

f. Each MMA has the authority to read and write both Knowledge Base and Subscription Base. A MMA searches the suppliers' information in these tables, then creates a SMA for each supplier and thereafter puts the serialized form of each SMA into the SMA Queue.

g. SMA Dispatcher sends each SMA in the SMA Queue to its target supplier.

h. Each SMA returns the result of its search and negotiation activity to the Manager via *getResult* method. These results are received by Result Manager and inserted into the Result Queue.

i. MMAs examine the results in the Result Queue carefully and make a decision. After reaching a decision, a MMA creates a decision report and puts it into the Decision Queue.

j. Notification Manager Sends each decision in the Decision Queue to its target Customer.

Manager Agent is the main component of Control/Optimize System. It has control over all operations in the system. It evaluates an incoming message and generates lists of target suppliers by using the information in Knowledge Base and Subscription Base. Manager Agent provides a platform for incoming mobile agents to run and create SMAs and dispatching them to the necessary suppliers. It also supports the registering and dispatching operations in accordance with publish/subscribe paradigm.

3.3.1 Vendor Selection Process

Traditionally, vendor selection and evaluation were based on picking the least invoice cost supplier, ignoring other important sources of indirect supplier costs like those associated with late delivery times, production breaks, poor quality of delivered goods, etc. A number of alternative approaches have been suggested to take the other factors into account, called rating models, summarizing several performance indicators into one score such as *Categorical Method*, *Weighted Point Plan*, *Analytical Hierarchy Process Method*. Some studies indicated that customer-supplier relationships are becoming more dependent on factors like quality, delivery performance, flexibility in contract, and commitment to work together, as opposed to traditional relationships based on cost [13].

In the supply chain, as in our case, we found that the decision-making process was centralized to a great extent, few suppliers were extremely important whereas others were mainly controlled by the manufacturer, and a major part of the supply chain was owned by the manufacturer.

We need improved clustering methods to group suppliers that accurately identify cluster membership and that are robust for a wide range of "messy data" conditions. Self Organizing Map (SOM) network as an alternative to conventional hierarchical clustering methods used today is used [14]. SOM neural networks correctly identify cluster membership in "messy data" sets.

The SOM network is a two layer, feed-forward network such that every output unit has incoming connection from every input unit. The geometric arrangement of the output layer is usually a linear array or a bi-dimensional (or sometimes even tri-dimensional) rectangular grid. Output layer maps *N*-dimensional input to *M*-dimensions (*M*=1,2, or 3), preserving topological order. The input layer of neurons is fully connected to the output layer. The output layer computes the Euclidean distance between the weight vector for each of the output neurons and the input pattern. The output neuron that is closest is the winner with an activation value of one while all other neurons have activations of zero. For the purpose of identifying cluster membership, we use one-dimensional Kohonen output layer.

The SOM network is trained by an unsupervised competitive learning algorithm [14]. The self organization process begins with all network weights initialized to a small random value. Training proceeds by repeatedly exposing the network to the entire set of input vectors. The winner neuron is determined with respect to distance values and the weights of this winning neuron are adjusted in the direction of the input vector. The weights of neurons included in the neighborhood set are also adjusted. The learning process continues with the presentation of input vectors in random order until Kohonen weight vectors stabilize.

4. SYSTEM PERFORMANCE

We have selected average order decision time as an appropriate benchmark for evaluating performance of a communication framework. We define order decision time as the elapsed time between order reception time and selection from the SMA Result reports. In our analysis, order generation is the submission of an order to the Control/Optimize Service by a customer. In our preliminary analysis, we established an objective of determining the efficiency of the Control/Optimize Service delivery without incurring concurrency into the system. Our goal was to examine the performance and scalability of the system.

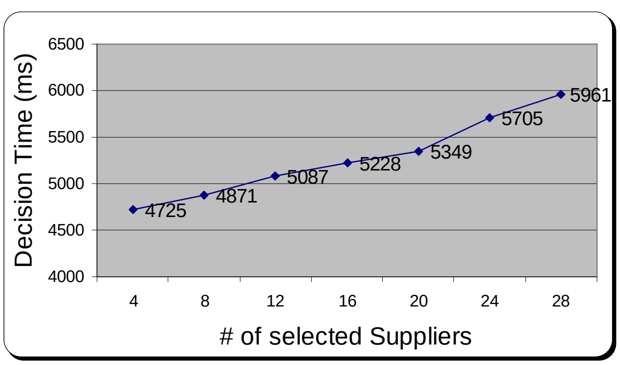

Figure 7. Order Distribution and Decision Times

We ran a simple benchmark with a single customer, one Manager and a multiple number of suppliers, which were distributed on the system. The number of suppliers that is selected by our vendor selection process, was varied from 4 to 28 on successive trials. The experiment used a single order source whose order generation rate was slow enough to allow all the listeners to have processed a given order before the next was generated. As we were sure that there was no concurrent order delivery, we could compute the theoretical best average delivery time. Figure 7 shows order distribution and decision times we have measured for increasing number of selected suppliers. (vendor selection by neural network is takes more than four seconds)

Although, our system has not been tested with very large number of subscribers and publishers, the results we have obtained show that our system is scalable.

5. CONCLUSION AND FUTURE WORKS

In summary, we have proposed a two level agent architecture that supports the decision-making requirements of e-commerce applications, which have continuously evolving needs. Our system's communication infrastructure based on publish/subscribe paradigm, which allows participants to join and leave the system dynamically, extending the flexibility and adaptability of the system. By using a two-leveled agent model, we have also made use parallel computation to enhance performance.

We use mobile agents as a mediator between customers and suppliers. The main advantage of using an agent-based approach is that the agents interact autonomously and power is devolved to the agents, i.e. there is no need for a super-agent to oversee the communication and interaction. This leads to better performance for us. Mobile agent-based procurement process is just the tip of the supply chain iceberg. Research on the other part of the system is still ongoing at Turkish Air Force Academy.

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