Multiagent-Based Model For ESCM

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Web based applications for Supply Chain Management (SCM) are now a necessity for every company in order to meet the increasing customer demands, to face the global competition and to make profit. Multiagent-based approach is appropriate for eSCM because it shows many of the characteristics a SCM system should have. For this reason, we have proposed a multiagent-based eSCM model which configures a virtual SC, automates the SC activities: selling, purchasing, manufacturing, planning, inventory, etc. This model will allow a better coordination of the supply chain network and will increase the effectiveness of Web and intelligent technologies employed in eSCM software.

Keywords: *Multiagent System, eSCM, Ontologies, Knowledge, ACL, KQML*

1 Introduction

Supply chain management involves various approaches used to integrate suppliers, manufacturers and distributors in performing their functions: materials procurement, materials transformation in intermediate and finished products, the distribution of these products to customers in the right quantities, to the right locations and at the right time to meet the required service level with minimal cost. Through collaboration and information sharing companies create high-performing value systems, providing member organizations an important competitive advantage [1].

Supply chain management refers to the management of processes and operations associated with the flow and transformation of goods from raw materials to finished goods until they arrive to the end user, together with the associated information flows.

SCM applications streamline these activities and enable collaborative demand and supply forecasting as well as control. In addition to demand and supply, it also includes inventory and transportation of these items down the supply chain. Backbone of the supply chain management is the information management system that links the different components of the supply chain together. Migration to eSCM - a Web based approach for SCM applications - is required for maintaining a consistent and predictable quality of service and controlled distribution of the data which otherwise cannot be achieved [2] .

Many technologies were used to automate and streamline SCM activities, but they could not provide enough flexibility to react in real time to market events. In this context, we present agent technology as an appropriate solution for designing Web enabled supply chain software, because it shows many of the characteristics a SCM system should have: autonomy, collaboration, proactiveness, adaptability, mobility.

2 Intelligent Agents and Agents Architectures

The term “agent” denotes a software-based computer system, which can act on behalf of its user to accomplish their tasks. The agent has the following features:

- Autonomy: agents perform most of their tasks without the direct intervention of humans and should have a degree of control over their own actions and their own internal state [3]
- Social ability: agents should be able to interact with other software agents and humans [3]
- Responsiveness: agents perceive their environment which can be the physical world, a user, a collection of other agents, the Internet, or perhaps all of these combined and respond in a timely fashion to changes occurring there.

- Proactiveness agents respond to their environment and should exhibit opportunistic, goal-directed behaviour and take the initiative when appropriate [3].
- Adaptability: the agent should be able to modify its behaviour over time in response to changing environmental conditions and to an enhanced knowledge about its problem-solving role
- Mobility: the agent should possess the ability to change its physical location to improve its problem-solving capacity
- Veracity: the assumption that an agent will not knowingly communicate false information
- Rationality: an agent should be expected to act in order to achieve its goals and not to prevent its goals from being achieved without good cause.

The main difference between objects and agents concepts is the autonomy of agents. Objects encapsulate some state on which their methods can perform actions, and in particular the action of invoking another object's method. More than objects, an agent has control over its own behaviour [3].

Agent technology also satisfies the fundamental requirements that a modern company will need: enterprise integration, distributed organization, interoperability, open and dynamic, structure; cooperation, integration of humans with software and hardware, agility, scalability, fault tolerance. In the same manner that there are several languages to implement agents, there are also different levels of complexity of this implementation. Such complexity depends on the task that agents have to carry out and on the environment they have to deal with. A classification of agent architectures is the following:

- simple reflex agents
- model-based reflex agents
- model-based, goal-based agents
- utility-based agents
- learning agents.

Utility-based agents find the best actions according to some given metrics, being much appropriate as Economics agents than the previous three architectures.

We consider that the autonomy, social ability, responsiveness, proactiveness, adaptability are the most important agent characteristics that provide the possibility to automate and synchronize supply chain activities in a effective manner and to reduce the amount of information needed for processing and sharing by humans or other specific applications. For this reason,

we will pursue to employ intelligent agents for managing internal and external processes in the supply chain by creating a model for a Web based SCM application.

3 Multiagent Systems for SCM – literature review

There is a general opinion that multiagent systems are generally less efficient than centralized solutions, because the distribution restrains optimization. However, there are several advantages of multiagent systems. First, multiagent systems are easier to understand and implement, when the problem itself is distributed [6]. Modelling with agents through dividing efficiently the problem space of a complex system, is a natural way to modularize complex systems, because this approach focuses on the organizational relationships in complex systems and give more flexibility. Multiagent systems have been used in many fields:

- Industrial applications: manufacturing, process control, telecommunications, air-traffic control, transportation systems
- Commercial applications: information management, business process management , electronic commerce: E-commerce agents can: replace us to look for the products that best fit our needs, bid for products on auctions sites, following a given strategy, try to form a coalition with agents buying a similar product, in order to have a price reduction due to the higher bought quantity . TAC (Trading Agent Competition) aims at confronting agents to find the best buying strategy in situations close to real-life, being used for supply chain management, too [3] .
- Entertainment applications: games, interactive theatre and cinema

- Medical Applications: patient monitoring, rescue team management [3]

Internet based SC applications use many technologies: information technology infrastructure (network, databases, etc.), e-commerce technologies (Electronic Data exchange -EDI, eXtended Markup Language - XML, Resource Description Framework – RDF, Web Ontology Language - OWL to give semantics to Web pages [4], the Common Business Library - CBL for describing documents such as orders or catalogues), supply chain components, (supply chain planning, i.e., Decision Support Systems). Information and decision technologies used nowadays are Enterprise Resource Planning (ERP) and e-commerce (in particular marketplaces) as „Transactional Information Technologies” and Advanced Planning and Scheduling (APS) (Decision Support System (DSS) in supply chains) as “Analytical Information Technologies” [5].

Multiagent systems are seen as a new technology for improving or replacing technologies used in both transactional and analytical information technologies. A reason supporting the usage of multiagent systems in supply chain management is that supply chains are made up of heterogeneous production subsystems gathered in vast dynamic and virtual coalitions. Intelligent distributed systems increase autonomy of each member in the supply chain. Each partner and its production subsystem can follow individual goals, satisfying at the same time local and external constraints. In an agent based SC, one or several agents can be used to represent each partner and the distributed manufacturing units because they have the same characteristics as agents: autonomy, social ability, reactivity and proactiveness in the market.

Agents are appropriate for e-SCM applications as they are modular, decentralized, changeable and complex. The optima computed by conventional systems may not be always deployed and predictions produced by conventional approaches are often invalidated by the real world.

Agent-based systems are a viable technology for the supporting e-SCM communication and decision-making in real-time, due to their adaptability, autonomy, reactiveness social ability. Each agent would represent a part of the decision-making process, thus results a network of decision makers, who react in real-time to customer requirements.

According to [3], there are two types of projects that use agents for SC: supply chain management projects and supply chain design projects.

- DragonChain simulates supply chain management, and especially reduces the bullwhip effect using the Beer Game.
- Agent Building Shell at the University of Toronto is a library of software classes providing reusable elements for building agent systems having four layers: a layer for knowledge management, an ontology layer, a layer of cooperation and conflict solving, and a layer of communication and coordination. This latter layer is insured by the COOrdination Language (COOL).
- MetaMorph II is an improvement of a first project called MetaMorph. Agents form a federation centred on mediators that have two roles: they allow agents to find each other, and they coordinate these agents. These two projects were developed at the University of Calgary (Alberta, Canada) by Maturana and others.
- NetMan (NETworked MANufacturing) formalizes networked organizations and production operations in order to obtain agile manufacturing networks in a dynamic environment. Company coordinate with each other and with other customers and suppliers based on contracts and conventions, which are formalized according to the model Convention, Agreement, Transaction (CAT). (Universite Laval Quebec City, Quebec, Canada) [5].
- MASCOT (MultiAgent Supply Chain cOordination Tool) is a reconfigurable, multilevel, agent-based architecture for planning and scheduling aimed at improving supply chain agility. It coordinates production among multiple internal or external facilities, and evaluates new

product/subcomponent designs and strategic business decisions (e.g., make-or-buy or supplier selection decisions) with regard to capacity and material requirements across the supply chain. Like BPMAT and SCL, this work was completed at Carnegie Mellon University (Pittsburgh, PA, USA).

- MASC studies coordination between companies in supply chains through calls for submissions. Submitters answer according to their capacity and production load. Companies that win this auction next take part in the supply chain carrying products to the consumer. [6]

There are many other agent based SC applications developed for eMarketplace, event management, resource management, model driven development and integration, risk management, trading, optimization, real-time operation, SC modelling in dynamic environment, coordination, planning, manufacturing, etc.

In the literature we have found many agent based approaches which deal with limited issues like negotiation, event management, resource management, etc. What we propose different from these previous approaches, is the automation and synchronization of SC activities at an extended level, comprising internal company functions and external SC collaboration activities. We focus our study on automating supply chain activities by using a multiagent architecture for Web based SCM, in which each agent can take decisions in real time to achieve its own goal and network goals and to satisfy customer requirements.

4 eSCM Architecture

We consider that there is not enough collaboration and valuable information sharing in supply chains so that to be able to provide the right product, at the right place and time so that to satisfy customer requirements and to maximize sales. The consequences of not collaborating with customer in real time can be seen on the market in every field of the economy: inadequate levels of inventories, unsatisfied demand, low service level, customer discontent, low income, low profits, late response to market changes and poor management of events in SC network. Collaboration and especially e-collaboration in the supply chain is the foundation for gaining competitive advantage and maintain market share so that to make profit.

In order to solve all these problems, we propose a model for information sharing in real time and automation of SC activities inside and outside the company among business partners. This model will allow a better knowledge of the market, of demand evolution in time, appropriate levels of inventories for raw materials and products, real time event management in SC, real time response to customer requirements. In order to achieve real time reaction to market changes, we propose the usage of intelligent agents to automate routine tasks so that to accelerate information sharing, collaboration and business processes in the supply chain.

For the design and implementation of the eSCM application, it is needed a technical architecture that enables the integration resulting from the linkage between computer systems and people. The integration merges operational functions allowing coordination of business processes in the network. Networking activates the linkages by enabling people to pass departmental and enterprise boundaries and to gather and share common knowledge to execute a wide range of business processes. Intelligent agents are meant to replace the employees who execute routine tasks and who collaborate inside and outside the company to perform all the operations needed in the supply chain network.

We present an e-SCM model, in the next figure. This model will be automated with intelligent agents.

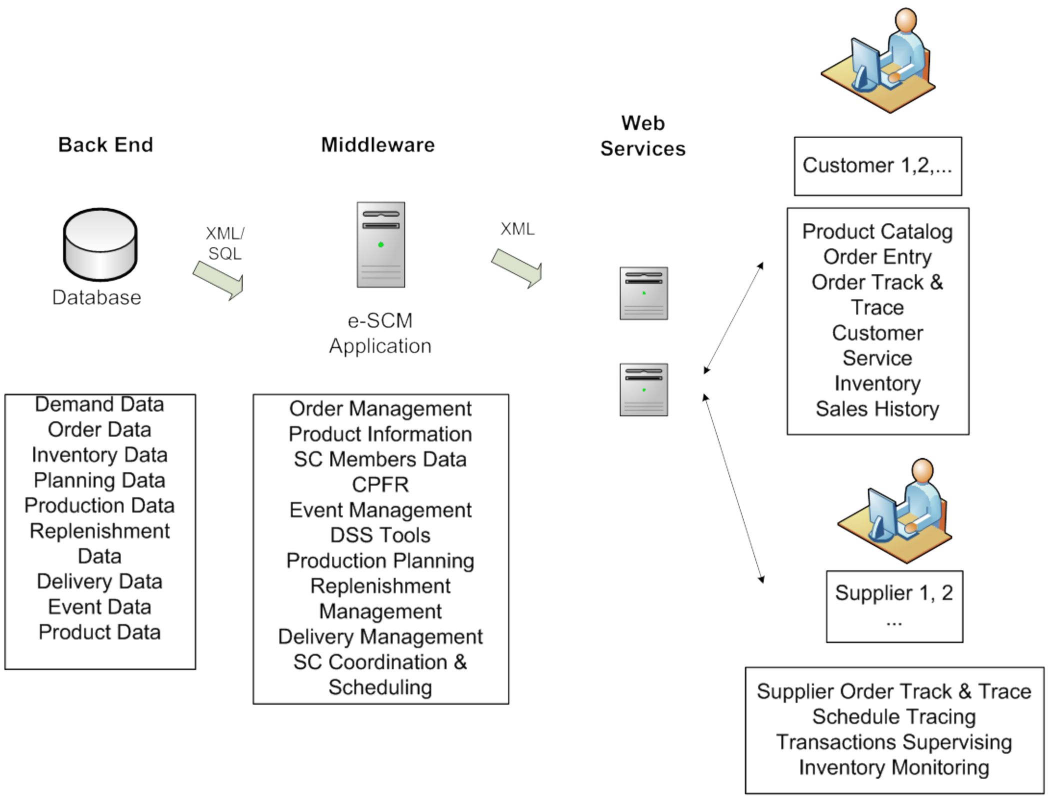

Fig. 1. The eSCM model

The e-SCM model presented above integrates the enterprise with suppliers, customers and partners. It is designed for the integration of different computer environments.

E-SCM application should have three tiers architecture with the following functions:

- Front-End Functions - should be capable of handling a wide volume of data. XML is used to integrate Web and server-based components. This tier includes an e-shop for customers and a panel for clients with order track & trace. Another module for this tier is suppliers' module which allows the monitoring of supplier orders, schedule tracing and transactions supervising.
- Middleware Functions - the front-end passes the external requests for further processing to the middleware application servers. Partners' data are extracted from their ERP systems and stored in a common database. The functions executed at this level are: order management, production tracing, collaborative forecasting and planning for demand, purchasing, manufacturing, delivery, agent based event management, demand analysis and monitoring. Intelligent agents supervise the execution of activities and trigger warnings when exceptions occur to the SC companies involved.
- Back-End Functions. Data warehousing is needed for real-time data mining, large databases and the utilization of analytical processing needs such as OLAP (Online Analytical Processing). The hardware should provide storage solutions for dynamic applications, scalability and flexibility.

The model can be extended to employ components for wireless usage that brings many advantages: allows SC applications to transmit real time data from the field, customer demand information is available in real time, employees can share information about activities and processes in the SC. Wireless technologies allow data access for collaborative information exchange and for tracking the position of items in the SC: RFID (Radio Frequency Identification) technology allows the real-time posting of data by mobile op-

erators so that to identify products location in the supply chain network.
The new features we propose for eSCM architecture are: the usage of software agents for SC event management and collaborative planning and forecasting, information sharing for right SC node, market analysis of customer requirements, proactive behaviour for the entire supply chain will bring competitive advantage and effectiveness.

5 Multiagent-Based Model for eSCM

Agent-based applications must be developed using established standards, especially in the area of process modelling and enterprise application integration [6]. For this reason we will present the technologies needed for the design and implementation of these applications. Communication is a key feature in multi-agent systems. Communication between agents is necessary to exchange information, to distribute tasks, plans and goals, to coordinate actions, to negotiate prices and resources, to manage shared resources and to recognize, avoid and manage conflicts. To enable negotiation between different agents, e.g. for task delegation, communicative acts are used, grounding on speech act theory. Examples of communicative acts are *cfp* (call for proposals) starting a contract negotiation between agents, or *request* to request an agent to perform some task. These communicative acts and additional information, like sender or receiver of a message, are covered by agent communication languages (ACLs) [7]. The main representatives of ACLs are FIPA-ACL from the standardization committee FIPA and KQML. Within ACL messages the content languages are used to code the real content of the message. Each ACL offers a minimal set of performatives to describe agent actions and allows users to extend them if the new defined ones conform to the rules of ACL syntax and semantics. In KQML there are no predefined performatives for agent negotiation [7].
FIPA Open Source is a open-agent platform that supports communication by using the FIPA agent communication language standards. It provides the set of platform service that are specified in the FIPA agent standards, including an agent management system (AMS) for lifecycle management, a directory facilitator (DF), a communication channel for FIPA compliant messaging and interaction protocols. FIPA OS include several agents shells that are base classes that make use of the platform services and that can be extended to add customized behaviours. A visualization tool gives the graphical interface to the FIPA OS platform. Although FIPA make no strong statements about the internal structure of the running on the agents platform, but relies on the BDI (Believe-Desire-Intention) agent model, expecting agents to have mental states, beliefs about other agents and the state of the world and desires and plans for taking actions to change the state of the world. Agents can take actions by interfacing with software outside of the agent platform or via speech acts exchanged with other agents. The FIPA agent communication specification includes interaction protocols for asking questions, sharing knowledge and participating in various types of auctions and negotiations [8].
JADE is a FIPA compliant toolkit for creating multiagent systems applications. JADE provides a set of tools for debugging and deploying distributed agents. JADE provides a set of agent services including an agent naming service, transport protocols, interactions protocols that are FIPA compliant. The agent platform can be distributed between several host systems, requiring a single Virtual Hosting Machine (JVM) on each to serve as the agent container. The communication infrastructure enables agents to access private message queues and provides support for FIPA encoding schemes and ontologies. JADE supports Remote Method Invocation (RMI), Common Object Request Broker Architecture Internet Inter-QRB Protocol (CORBA IIOP) and event notification transport protocols. Each JADE agent has a single thread by default but can use Java multithreading capability. Jade supports complex scheduling of agent tasks as well as integration with the Java Expert System Shell (JESS) reasoning engine. A GUI allows re-

mote monitoring and control of agents that are running on the Jade agent platform [7].
Companies in the supply chain have their own interests which cannot easily be modelled through agent cooperation as a pure scheduling problem. The supply chain network is a flexible and adaptive framework in which companies may join or leave according to their policies.
Agents have to cooperate in a relatively dynamic way. To address this problem, we propose a multiagent framework based on collaboration for supply chain management.
In our framework, there are stable relationships between functional agents, but new partners are accepted if they want to join the network. New partners can choose to engage in short or medium term relationships.
For short term relationships agents will negotiate with each other in order to reach an agreement. When an order comes, a virtual supply chain may emerge through negotiation processes. For medium or long term relationships, partner companies will have to settle on a contract. Every type of order received from the customers is managed according to the contract terms and rules. Once the contracts settled, the agents representing each company will work according to the terms of the contracts in the supply chain. Thus, collaboration involves a set of rules established through medium or long term contracts and negotiation for short term relationship.

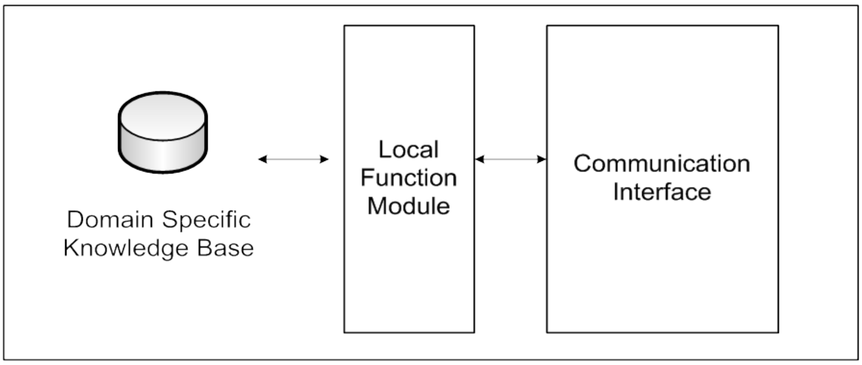

Fig. 2. The structure of an agent

Figure 2 shows the structure of an agent. There are several layers in the agent structure:

- The communication interface enables the communication between agents through methods or functions. Messages exchanged are related to domain-independent and domain-dependent content specifications.
- Local organization module includes organization model and deals especially with manufacturing model. Agents can communicate by using KQML syntax in order to collaborate to manage the orders according to a set schedule and respecting a set of rules. Communication rules and models enable the coordination of the agents [9]. Agents' functions and inference algorithms are written in Java.
- Knowledge base is specific for manufacturing domain and includes manufacturing models, tasks, interdictions and obligations: agents' management and coordination, order management, production, inventory management, logistics, transportation. Each agent has its own function in the manufacturing and delivery process and its expertise (algorithms and rules) for its tasks.

For knowledge representation we will use Knowledge Interchange Format (KIF), and for message-handling protocol Knowledge Query Manipulation Language (KQML) to support run-time knowledge sharing among agents. KQML is the language used for the application program to interact with an intelligent system and KIF as a computer-oriented language for the interchange of knowledge among heterogynous programs. For implementation we will use JADE toolkit.

The MAS model we propose has a hybrid structure. The agents at the lower level are also intelligent and have limited autonomy, being able to decide issues concerning their own activities. They are coordinated by the agents from the next higher level, which have a wider perspective on the activities executed by their subordinate agents. These supervisor agents take decisions involving their subordinates and collaborate with other agents from the same level. The goal of this model is to provide autonomy and adaptability for agents and to obtain efficiency from the hierarchical structure.

The proposed model has functional agents which represent companies with their own interests and may join or leave the network according to their considerations. The model can adapt to the environment changes, optimizing the real time reaction in eSCM, this being one of the main goals of SCM applications [10]. Agent descriptions provide an ability to specify both static and dynamic characteristics of various supply chain entities.

The model will have eleven agents which will solve specific problems related to selling, order management, manufacturing, purchasing, planning, coordination, logistics, transportation etc. All agents understand system ontology and use KQML to communicate. The system ontology includes knowledge about the issues that the system is dealing with and interaction rules:

- Selling Agent (SAg): This agent contacts and interacts with many outside purchasing agents owned by distributors, retailers, customers, which contains the constraints for supply and maintain quote. It sends offers to customers in response to RFQs. This model is used for those partners who are engaged in short term relationships. For long term relationships the selling agents will use a different model which doesn't involve negotiation, only receiving the order and sending it to the order agent so that to be fulfilled according to the contract between SC partners.
- An Order Agent (OAg): is created for each received order; its goal is to obtain the products needed to fill the order and ship them to the customer.
- Purchasing agent (PAg): these agents provide RFQs and orders for the suppliers. This agent contacts and interacts with many outside selling agents owned by suppliers, which contains the constraints for order management, fill orders and deliver materials to the manufacturer. RFQs are for short term relationships model which involve negotiations. The purchasing model for medium or long term relationship involves sending purchasing orders to company's suppliers acoording to settled contracts between SC partners.
- A Production Agent (PrAg): provides production cycles; this is a bottleneck resource, because only a fixed production capacity is available per month. The agent controls the manufacturing process, which contains the constraints for monitoring the operation, production scheduling, and monitoring the quantity of raw materials. The production agent has as subordinates the Component Agent and the Assembler Agent and is situated at the same level with the Scheduling Agent. The Production Agent and Scheduling Agent are supervised by the Manager Agent.
- Component Agent (CAg) is assigned for each of the components types; these agents provide information about each component and its prices communicated by PA.
- Scheduling Agent (ScAg) is responsible for scheduling and rescheduling activities in the company, using "what-if" scenarios for potential new orders. It generates schedules that are sent to the other agents for execution. It assigns resources and start times to activities, optimizes certain criteria such as minimizing work in progress, cost or tardiness. The Scheduling Agent has as subordinates the Component Agent, the Inventory Agent, Logistics Agent and Transportation Agent.

- An Assembler Agent (AssAg) is assigned for each of the products; it obtains components from the CAgs and production cycles from the PrAg and then delivers finished products to the Order Agents.
- Inventory Agent (IAg): The agent controls the inventory levels, which contains the

constraints for monitoring inventory flows, acquire information from manager agent to

calculate necessary materials based on historical data for optimal reorder quantities, also

chooses inventory replenishment policy; generates delivery plan, and safety stock.

When resources do not arrive as expected, it assists the scheduler in exploring alternatives

to the schedule by generating alternative resource plans.

- Logistics Agent (LAg). This agent is responsible for coordinating activities to achieve the best possible results in terms of the goals of the supply chain, including on-time delivery and cost minimization. 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(TrAg). This agent is responsible for the assignment and scheduling of transportation resources to satisfy network movement requests specified by the logistics agent. It can consider a variety of transportation assets and transportation routes in the construction of its schedules.
- Manager Agent (MnAg): The agent manages and controls all the above-mentioned agents. At the same time, these agents are designed for providing system information. Manager agent uses local database that stores all related information. This agent performs real-time control functions as planned by the scheduling agent and coordinates activities to respond to latest events: modifications to customer orders, resource unavailable from suppliers. In dealing with stochastic events, the agents must make optimal decisions based on complex global criteria that are not completely known by any one agent and may be contradictory and therefore require trade-offs executed by the manager agent.

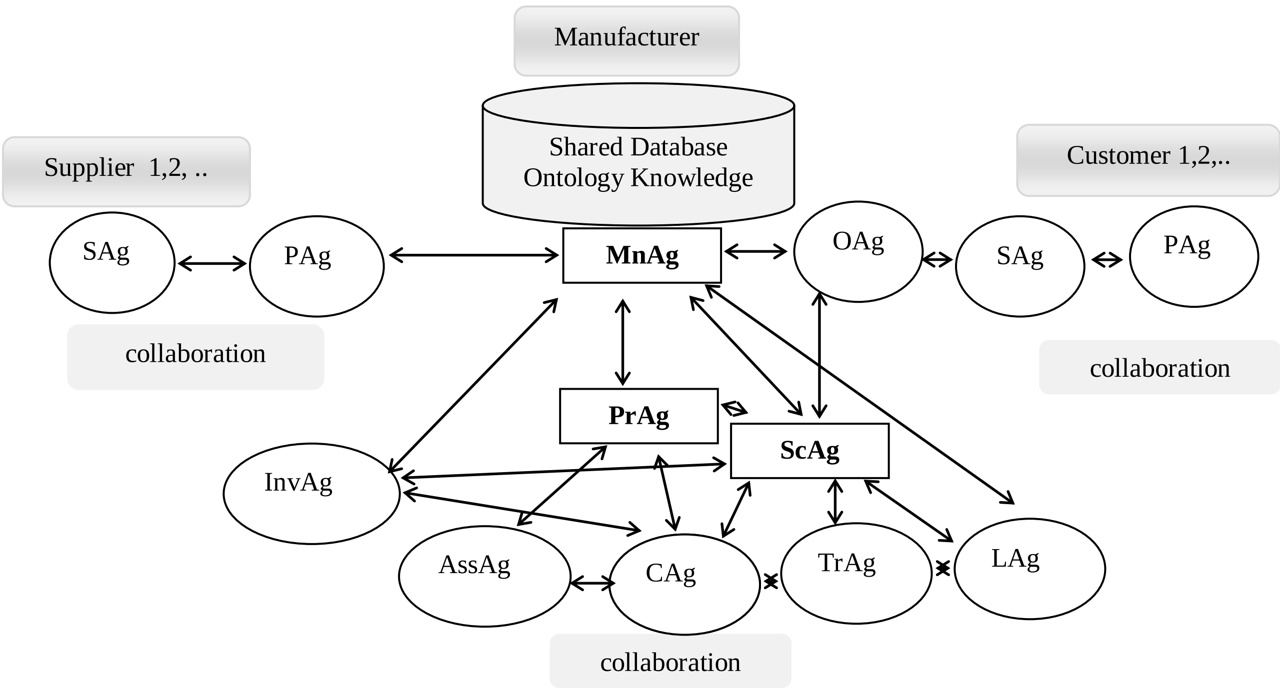

Fig. 3. Multiagent-Based eSCM Model

The agents in rectangles are situated upper in the multiagent model hierarchy, while the agents represented through ellipses are subordinated agents, situated on a lower level in the multiagent system. As we have specified in the previous subsections, there are short, medium and long term relationships between agents that are approached using two different models. The short term relationships model is described in the following subsection.

The customers that need our company's products begin to search the Web to find our Purchasing Agent (PAg). When they find our agent, they will start the negotiation with our Selling Agent (SAg). The negotiation ends when a deal takes place. The customer decides to buy our product and the Selling Agent (SAg) receives an order from Purchasing Agent (PAg).

The selling model for medium or long term relationships is based on preset contracts and agents are fulfilling customers' orders according to these contracts. Once an order entered in the system it is approached in such a way that the order requirements to be executed as soon as possible.

The order is sent to Order agent (OAg) which monitors it and passes it to the Scheduling Agent (PrAg) and the Inventory Agent (IAg). Scheduling Agent (ScAg) checks the possibility to supply the order, decide the production plan, make the scheduling, and inform the Manager Agent (MnAg). Inventory Agent (IAg) together with Component Agent (CAg) and Assembler Agent (AsAg) checks the requirements of raw materials and inform Manager Agent (MnAg). Manager Agent (MnAg) decides to purchase the necessary raw materials, and sends the information to company Purchasing Agent (PAg).

For the short term relationships model, the Purchasing Agent (PA) negotiates with suppliers' Selling Agents (SA) until one deal takes place. The Purchasing Agent (PA) decides to buy from the supplier which best satisfies the acquisition conditions and sends the chosen supplier's Selling Agents (SA) the order for raw materials or components.

The purchasing model for medium or long term relationships is based on preset contracts with suppliers and purchasing agents are sending procurement orders according to these contracts.

When the supplier completes our company order and confirms the order to the Purchasing Agent (PA) with the date and place of delivery of the raw materials, the Purchasing Agent (PA) passes the order delivery information to the Logistic Agent (LAg) and Transportation Agent (TrAg) which passes the order delivery information to both the Scheduling Agent (ScAg) and the Inventory Agent (IAg). Inventory Agent (IAg) announces Scheduling Agent (ScAg) the receiving of raw materials and components. Scheduling Agent (ScAg) decides the production schedule to fulfil the customer order and communicate with Production Agent (PrAg) to decide the production plan. Assembler Agent (AssAg) obtains the products from the components from to (Component Agent) CAg and announces the Order Agent (OAg) and Inventory Agent (IAg) about this. OAg will ask the Logistic Agent (LAg) and Transportation Agent (TrAg) to schedule the delivery of products to the customer. The Selling Agents (SA) transmits the information of the date and the shipping address for the ordered products to the customer's Purchasing Agent (PA). The Manager Agent (MA) will be informed about these activities.

The negotiation for selling products has to take into consideration several conditions related to price, quantity and delivery time and to check if the demanded products exist in the warehouse or can be produced to be delivered on time. If the requirements can be met, the selling agent will send the customer's purchasing agent the answer yes for its demand. If customer's PAg considers our offer the best one, the agreement will be settled and the customer will send an order, if not, the negotiation will be cancelled by parties. For purchasing, company purchasing agent send requests for quotation to suppliers' selling agents and negotiate with them for the price, quantity and delivery time. When these requirements are met, the deal will be settled, if they cannot be met, the negotiation is cancelled.

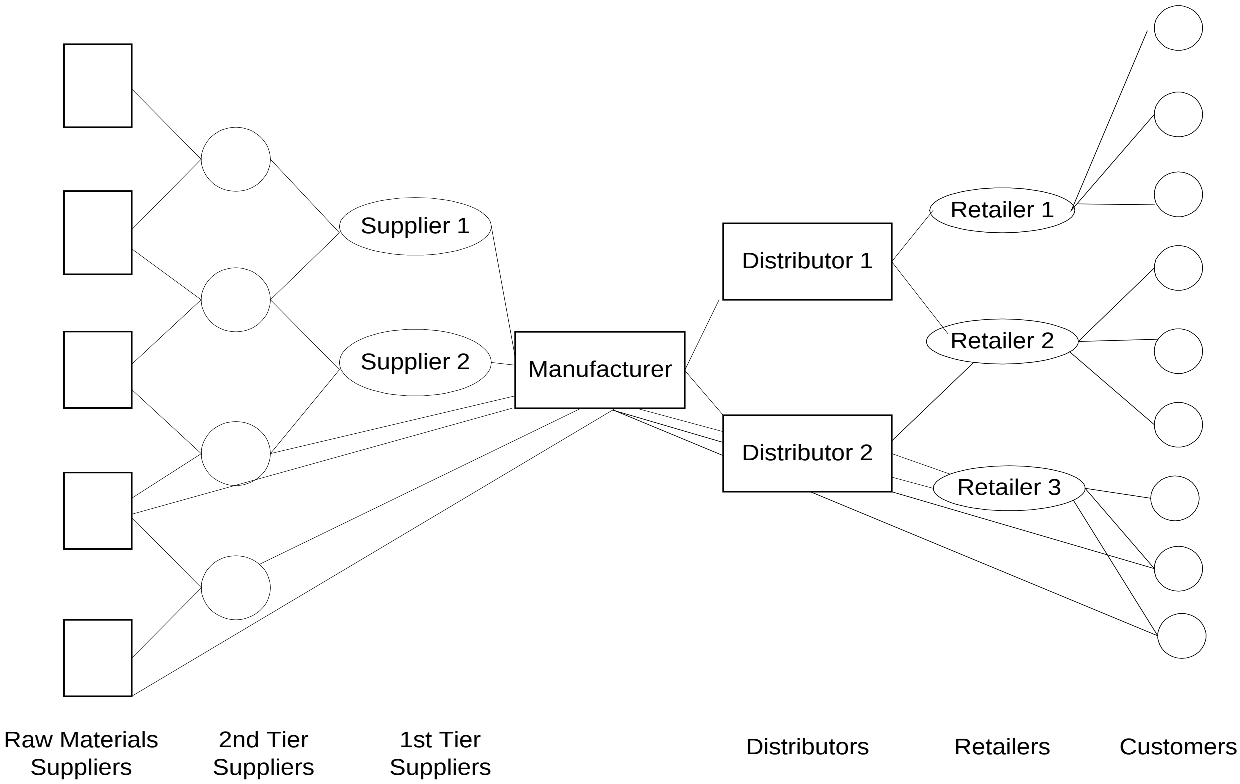

Fig. 4. The networked e-SCM

The supply chain has evolved from a linear chain to a networked supply chain. The networked supply chain allows increased in demand visibility, operational efficiency, customer segmentation and the decrease of procurement and inventory costs, replenishment time, etc. All these facilitated the evolution of SCM (Supply Chain Management) applications from transaction based to collaborative and synchronized systems. The value chain has extended from first tier partners to groups of tiers forming a networked supply chain. The collaboration can be achieved through settled relationships resulting in contracts between partners and common procedures. The processes and operations can be automated by using intelligent agents not only for one company or one tier, but for the whole SC network. As we can see in the figure, the relationships can be extended from the manufacturer to the 2^{nd} tier suppliers and raw materials suppliers. Once an order arrives, the manufacturer can send the purchasing orders directly to the 2^{nd} and 3^{rd} tier suppliers so that to quicken the whole purchasing process, eliminating intermediates. The agents can communicate to each other to manage operations, events and exceptions for every tier in the SC.

Every change in customers' orders can be transmitted directly to the manufacturer, without involving retailers or distributors to communicate information. Information and operations visibility is provided by the automated e-SCM applications through Web technologies and intelligent agents so that every member involved in order fulfilment will be able to trace the order and react if necessary.

The automated eSCM needs communication agents to share the right information to the right SC partner, specific purchasing agents to execute procurements functions and order agents to manage the changes in order terms. For sales, selling agents are needed for negotiation with customers and selling process. We need to employ a supervisor agent to monitor market changes and customer behaviour and clients requirements so that to be able to behave proactively. In order to automate the entire network by using intelligent agents, we need network rules as a foundation for network collaboration and a network interface for those agents that work with external agents from other companies. Data can be extracted from real time POS databases, customer wishlists, customer profiles stored in CRM applications, sales history etc. We can make correlations between this data by using decision support tools (such as artificial intelligent techniques, mathematics, statistics, etc) so that to discover patterns and trends in customer demand and to be able to foresee the future demand concerning quantity and mix of products.

Collaboration, usage of Web technologies and AI tools allow real time reaction on the market, can reduce the bullwhip effect existent in every supply chain and enables better planning and forecasting so that to be able to offer the right product or service, at the right time, to the rights place to satisfy customer requirements.

The model we proposed intends to solve the problem of automating activities in eSCM in real time without or with a limited human intervention. The utility of such an application is to manage real time information, events and demand faster, more effective and in a coordinated manner so that to synchronize the entire supply chain [10]. Our contribution to eSCM optimization is the employment of intelligent agents for the entire SC network so that to use their main features which provide SC network autonomy, adaptability and agility to respond to changing customer requirements and market conditions. In our future work, we will implement our model and will create a prototype of eSCM model based on the architecture proposed in this paper. There are issues that have to be solved concerning intelligent agents used for automating SC activities: effective collaboration between agents so that to provide optimal solution for the company and for the network, combining the cloud computing technologies with agent technologies for a more efficient SCM, synchronizing agents' activities in order to emulate to human expertise in solving companies' and network's problems.

The agent technologies have to be developed and employed in SCM applications so that to replace humans for routine and even for more complicated tasks. We consider that multi-agent systems together with Web technologies can automate and optimize SC processes. They can be employed and refined for eSCM applications and they will represent a reliable software framework in the future.

6 Conclusions

The multiagent-based supply eSCM application is distributed, dynamic, integrated, reactive, flexible, reconfigurable, interactive, due to the implementation of software agents witch execute SCM functions. They collaborate together and with human users to provide the best solution and use their expertise to accomplish their functions. We have proposed a model for automating the activities in the supply chain: selling, purchasing, manufacturing, inventory management, planning, logistics management, transportation, supply chain coordination etc. Our approach shows a new perspective on the value chain which can be modelled using intelligent agents that collaborate dynamically to respond in real time to market changes and adapt to customer requirements. The purpose of this multiagent based eSCM model is to automate all the activities and to optimize the collaboration in eSCM. The conclusion of designing this multiagent-based model for eSCM is that agent technology will reduce the cost of designing and implementing eSCM software and together with new Web technologies; they can provide a reliable software framework.

In our future work we intend to develop the model and to implement it for further automation of SCM activities, inside and outside company boundaries. Thus, companies in the e-SCM network can make their activities more efficient and add more value for both the companies and the customers which result in higher profits.

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