AN ORDER PLANNING SYSTEM TO SUPPORT NETWORKED SUPPLY CHAINS

Américo Azevedo^{1,2}, César Toscano², Jorge P. Sousa^{1,2}

¹*Faculdade de Engenharia da Universidade do Porto, Rua Roberto Frias,
4200-465 Porto, PORTUGAL*

²*INESC Porto - Rua José Falcão 110, 4050-315 Porto, PORTUGAL
email: {aazevedo, ctoscano, jsousa}@inescporto.pt*

In this paper we present an information system architecture, addressing the needs of an advanced order planning system for industrial networked enterprises environments. Firstly, the general objectives of the system are described focusing on the relevant business processes identified. Then, the related general functionality (business solutions) of a distributed system supporting those processes is described, focusing on the particular case of order change acceptance. An agent based architecture supporting this business solution is outlined, emphasizing the agent framework and the legacy systems integration.

1. INTRODUCTION

There is an increasing interest in exploring the opportunities for competitive advantage that arise from reinforcing core competencies and innovative capabilities through networks of industrial business partners, forming integrated Supply Networks known generically as Supply Chains or Networks.

The need to dynamically manage complex supply chain networks implies fundamental changes in the design of information systems with regard to planning and co-ordination activities (Azevedo and Toscano, 1999). However, in general commercially available information systems (such as ERP and SCM application packages) are not well suited to cover the issues arising in networked organisations.

Given the gaps in current available systems that claim to support eBusiness and eWork in organisations of networked enterprises, we propose a new concept for the design of a distributed Information System, that responds to the basic requirements of co-operativeness, integration and configurability.

The present research work is the outcome of an European Community IST project, called CO-OPERATE. A system prototype is being evaluated in specific automotive and semiconductor pilot companies, which are part of rather complex and dynamic production networks. This prototype is able to plan order requests across the entire production network using capacity feasibility checking through local capacity models.

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1.1 General features of networked enterprises

In today's economic environment, networked and "virtual" enterprises are becoming a new organisational paradigm, creating challenging opportunities in terms of management. These organisational networks are characterised by intensive communication between the participating companies, leading to large flows of information. In this environment, logistic issues are becoming more and more important, as a result of a radical change from a mainly centralised and nationally focussed economy to a worldwide distributed one (Thomas et al., 1996).

Setting up the network and managing it in an optimised way, balancing customer needs with increased performance along the whole chain, may be a key factor for the competitiveness of a company. This is particularly important in the complex and highly dynamic environments of the automotive and electronic industries. In this context, a major challenge consists in ensuring that the supply chain or network is viewed as a whole, by integrating the various distributed business processes, and by making relevant information available to all entities.

Three main types of network arrangements may be identified (Miers and Hutton, 1997):

Dominant organisation with a network of suppliers

This model is often used within large organisations, where one dominant player sets the main rules and uses a network of small firms to meet its needs and those of its customers. In this type of relationship, processes are usually focused on the repetitive supply of a service or product. The terms of the relationship are in general well defined in advance.

Co-operative network

This model involves networks of small businesses working together to support larger projects or services (which in turn may be supplied to larger or more dominant players). Processes are project oriented and require a trust relationship between all co-operating entities. This type of networks has an enormous potential for growth. Currently there are no suitable technology solutions to support this kind of model.

Virtual teams

The trend in most large businesses is towards having teams that are managed on a project by project basis (seeking for a more agile structure).

2. THE CO-OPERATE PROJECT

The IST-project 12259 Co-OPERATE is a project supported by the European Commission, that aims at developing solutions to enhance the entire supply network, providing an advanced information and communication infrastructure to support general co-operation, as well as particular methodologies for co-operative planning and for network set-up and support (Collings and Loeh, 2000). The project started in January 2000, and is targeted at the automotive and electronics industries covering several production stages consisting of large corporations and SMEs. The project

partners are: Imperial College (UK), INESC Porto (Portugal), Druid (UK), Siemens Automotive (Germany), Alcatel Microelectronics (Belgium) and MEMC Electronic Materials (Italy).

Business processes have been identified and a conceptual framework and methodologies for aggregate planning are being tested and tailored in the pilot companies. Hopefully they will be extensively applicable and easy to adapt to other industries. A brief description of the most important business solution follows.

Long term business planning for the network

This business solution will improve the long term planning process in the whole supply network. The goal is to generate long-term plans for the network by synchronising forecasts and plans, and by promoting early communication of changes and feedback about feasibility.

Standard operational order and planning processes

This business solution will support the short and medium term operational order and planning processes. This includes order generation and transmission, synchronised planning, monitoring and status information. This business solution should provide a strong basis for real-time order promising and exceptions handling.

Feasibility studies for new order or change requests across the network

This business solution will support the request for new orders or large order changes across the network and will support and co-ordinate the feasibility checks at the individual companies within the shortest possible time. This includes checking of capacity and materials from suppliers.

Exception handling process

This business solution will include methodologies to detect, as early as possible, problems in the network such as peak orders, capacity shortages or part availability problems.

Business processes have been modelled and analysed and a conceptual framework and methodologies for aggregate planning are being tested and tailored in the pilot companies. The prototype developed so far, based in an advanced multi-agent architecture (Sycara, 1998), is able to plan order requests across the entire production network using capacity feasibility checking though local capacity models (Leach and Ristic, 1998). These models make use of algorithms that are customised, configured and optimised for each production unit implementation.

The approach followed in the project goes in the same direction of other research works, see e.g. Shen and Norrie state-of-the-art survey (Shen and Norrie, 1999).

3. AN AGENT BASED ARCHITECTURE

A distributed architecture based on agent technology and extensively using the internet is being designed, as a means to implement new and more powerful decision support systems to be used in these type of environments, in a more flexible,

scalable and easy to configure way (Azevedo et al., 2000). The architecture is structured around the following basic architectural principles:

- each business unit in the network of companies will be served by a set of agents;
- each of these sets will form a "node" in a community of agents distributed by the several "units" in the network;
- in each node, the agents co-operate to achieve local goals;
- in each node, each agent performs one or more functions, and co-ordinates its decisions with other agents in the same node;
- different nodes in the network co-operate to achieve global or local network goals; the node co-operation is carried out by individual agents co-operation in the different nodes;
- the functionality across the network or supply-chain is achieved through the interaction of the different nodes;
- the number and types of agents present in each node may be variable.

3.1. Order promising process

For the general functionality of business solution "feasibility studies for new order or change requests across the network" (order promising process), we consider one scenario that assumes that a core company, with their own customers – downstream in the chain, is customer of a number of suppliers. The suppliers can request actualisation of orders either by a pull or push process.

We identify four kinds of actors: the customer of the core company, the expeditor at the core company, the supplier and the enterprise information systems (typically an ERP system) of the core company.

Concerning the main tasks, we have identified the following:

Order transmission

Allows to send automatically information to all suppliers using the best communication channel; all orders from the core company to each supplier are presented together with their actual status; the supplier has the choice to view them sorted according to a customisable filter; all new and changed orders (which not yet have been acknowledged by the supplier) are highlighted.

Acknowledgement of orders

The planner of the supplier can acknowledge each new or changed order and automatically the system registers the acknowledgement data such as date/time, user identification, etc; all changes are stored in a history table.

Order request

This task deals with the feasibility of acceptance of new orders, with the production of a quotation, with a real-time check of capacity and materials availability; this task supports and co-ordinates the feasibility checks at the individual companies within the shortest possible time including checking for own capacities and requesting needed materials from suppliers, which need to do the same process themselves.

Track Order

Basically this unity of functionality allows an end-customer or a supplier, to track, along the production chain, the positioning and the status of each related order.

3.2. Structure of a network node

Each node in the network is organized as a collection of roles. The roles have certain relationships to one another, and take part in systematic and institutionalised patterns of interactions (Wooldridge et al., 2000). As a whole, the system is viewed as a set of roles that:

- interact with each other according to some protocol;
- have responsibilities, which in a direct or indirect way determine the functionality inherent to that role;
- have a set of permissions, which identify the “rights” associated with the role, and subsequently identify the resources that are available to that role when its responsibilities are placed into practice;
- perform local computations or activities (local in the sense that no interactions are carried out with any other role in the system).

These abstract entities were used to derive more concrete entities, in terms of the agent types that make up the system, the services required to realise the agent’s role and the required acquaintances or patterns of communication between the different agent types. Table 1 identifies the agent types to support the organisation of each node in the network. Basically, an agent type corresponds to a certain combination of roles. This may be a one-to-one correspondence (a very unusual case) or a many-to-one mapping. This is the normal case, where a set of roles is attached to a single entity, being this allocation driven by a number of different types of requirements. Necessarily, these agent types are instantiated into agents for each site implementation, requiring the necessary interface with the human agents.

Table 1 – Types of Agents

Legacy Information Integrator	-Provides an information service; -Collects and aggregates information supplied from different legacy sources; -Propagates information to other required agent types.
Facilitator	-Acts as an organisational agent and is responsible for providing support to other agents; it provides, for example, services to find the location of external agents of a given type or having certain specific skills or properties.
Co-operative Planner	-Co-operates with other planners in other nodes, in order to develop plans that achieve the network goals; -Interacts with the local Capacity Agent;
Capacity Agent	-Dynamically evaluates the availability of the business unit for order requests; -Integrates a local Capacity Model with tailored algorithms; -Interacts with the Co-operative Planner and the Legacy Information Integrator.

Monitor	<ul style="list-style-type: none">-Acquires and aggregates the network or supply-chain state variables; compares current state variables with target values;-Identifies deviations or disruptions, e.g. resource failure (loss of production capacity), logistics problems (transport delays), quality issues;-Propagates warnings to other agent types.
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The basic agent architecture for each network node is represented in figure 1. Necessarily, these agent types are instantiated into agents for each site implementation, requiring the necessary interface with the human agents, namely the planner and the configurator.

Figure 1 – Organisation of Agents in a network node

The Monitor agents of each network node establish conversations between each other in order to support the propagation of events detected locally. Similarly, the insertion of a new order in the system is accomplished by negotiations carried on between Planner agents. Facilitator agents, located in certain places of the system, help to establish conversations and negotiation tasks between the Planner and Monitor Agents.

Each business unit in the network is represented by a set of agents that have the capability to engage in local conversations between themselves. Negotiation processes between two different businesses units are accomplished through the correspondent Planner Agents and it is supported by a variation of the contract-net protocol. There are two types of entities in a negotiation dialog: the initiator, which starts the conversation process, and the respondents.

A negotiation process is started when the Initiator formulates and issues a request-for-proposal message to a group of previously selected targets. Each of these entities either refuses the request, or construct and send a proposal to the Initiator. This call for proposals and subsequent interaction may be repeated several times. At

each stage, each respondent Planner Agent constructs a response, based on the current unit status and the adopted general planning strategies. The negotiation terminates as soon as the Initiator, according to its local strategy, decides to accept one of the proposals analysed in the latest iteration, and to refuse all the others. Research is currently being conducted in order to design appropriate strategies for the initiator role and for the respondent role of the negotiation process.

A first prototype of the multi-agent system was developed, and is being subject to evaluation and testing by the end users of the Co-OPERATE consortium.

The development work was done on top of the FIPA-OS framework (Poslad et al., 2000). This is an open agent platform, previously delivered by Nortel Networks and presently maintained by Emorphia (<http://www.emorphia.com>). An application server hides the software agents and dynamically constructs HTML pages with which the Users interact, through a standard Internet browser. The intended effects were threefold: to provide the planner in a given business unit, with an easy way to access its software agent; to make the software agent reachable at any time and from any place in the Internet; and to hide the complexity of the software from the end-user.

3.3. Integration with legacy systems

One of the main concerns in designing solutions for heterogeneous companies organised in supply networks is obviously the integration with the management systems running in those companies. In Co-OPERATE, a generic integration interface infrastructure was designed. This infrastructure is then deployed on top of the existing systems or infrastructures, to support the network processes of co-operation between the companies, complementing the processes managed by the existing systems.

In the single node context, integration with the existing legacy systems is divided in two phases. The first phase deals with connectivity between the different systems. For each legacy system, a software program must be available for converting raw data, presented in a specific and usually proprietary format, into a general and standard format. XML was chosen for this purpose, mainly because it is currently recognised as an official (or standard) language to describe data in the Internet environment and also because there are some ongoing efforts by specific segments in the industry trying to develop specific XML applications (RosettaNet, ebXML, Microsoft BizTalk, etc). This approach reduces the original integration problem to a more specific problem of converting data coded in different formats into generic and recognizable conceptual data.

The Legacy Agent accomplishes the second phase of the integration. Its purpose is to collect, process and assemble the raw data managed by the legacy systems (such as ERP and MES systems) and provide high-level conceptual data, required by the agents to perform their tasks. Normally, the low-level raw data is too detailed to be directly used by the agents in the system. Additionally, data coming from different sources may be insufficient and/or originate conflicts in the subsequent aggregation of the high levels data models. Development of appropriate abstractions and aggregations in the low level data is the main functionality of this layer. Further, the Legacy Agent mechanisms should be prepared to deal with inconsistencies, conflicts and inaccuracy in the data that is provided by the legacy systems. Due to

these limitations, the Legacy Agent must provide the necessary interface with a human expert analyst, in order to validate and set the necessary values regarding the configuration of parameters.

4. CONCLUSIONS

The interaction among participants in a network of companies, their co-ordination and their access to knowledge are becoming increasingly important. Moreover, setting up the network and managing it in an optimised way, balancing customer needs with increased performance along the whole chain, may be a key factor for the competitiveness of a company.

In the IST-project Co-OPERATE, the authors are actively contributing to the design and assessment of new forms of approaching tactical problems in enterprise networks, based on these new paradigms. A distributed and decentralised information system, based on an architecture of agents, and extensively using the internet, is being designed and implemented, as a means to provide new and more powerful decision support tools for this type of environments.

The general process and framework for the development of this system was briefly described in this paper, but obviously further research is needed in understanding the mechanisms of decision-making for networked enterprises and there is still a lot of research to do for improving network co-ordination, as well as local decision-making.

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