AGILE SUPPLY-CHAIN COORDINATION IN THE VIRTUAL ENTERPRISE

Ricardo J. Rabelo, Alexandra P. Klen, Luiz M. Spinosa, Aureo C. Ferreira
G-SIGMA - Intelligent Manufacturing Systems Group
UFSC / EMC / GRUCON – Cx. Postal 476
CEP 88040-900 – Florianópolis - SC

Abstract: In this work the supply-chain co-ordination in the virtual enterprise environment is subject of deeper analysis. The system developed by UFSC – DBPMS – for the management of distributed business process is presented and some basic concepts for its definition and development are detailed. The DBPMS provides means for getting, analyzing, making available and managing the information from and about a virtual enterprise, enabling the enterprises to make their logistics more efficiently by means of a integrated information-based supply-chain management

Keywords: Virtual Enterprise, Supply Chain Management.

1 INTRODUCTION

Even more the use of information technology is being encouraged for sharing and exchanging information right across individuals and organizations. This trend can be understood as a consequence of a new strategy of conducting business, which is the concept of Virtual Enterprises (VE). According to the terminology and definition used by the project consortium (Prodnet, 1996; Camarinha-Matos &al., 1997)¹, the paradigm of virtual enterprise is a temporary alliance of enterprises that come together to share skills and resources in order to better respond to business opportunities and whose cooperation is supported by computer networks and adequate Information Technology (IT) tools and protocols.

In the manufacturing sector, the Virtual enterprise is mostly composed by small and medium-sized enterprises behaving as suppliers and having no definite relations, policies and implications. Therefore, it is not difficult to perceive the degree of complexity to manage this kind of value-chain as well as to co-ordinate the logistics of a business process that is distributed.

The PRODNET-II (Production Flaning and Management in an Extended Enterprise) is a three-year (October/96 - September/99) international cooperation project supported by the European Union and by the CNPq (the Brazilian Council for Technological Development and Research). The project aims to design and develop an open platform and the adequate IT protocols and mechanisms to support industrial virtual enterprises with special focus on the needs of small and medium sized enterprises (SMEs). PRODNET-II focuses on means to inter-operate with several value chain networks employing new emerging standards and advanced technologies in communication, cooperative information management and distributed decision making.

As a general requirement for an infrastructure to support VEs, it can be pointed out that the companies must be able to inter-operate and exchange information in real time so that they can work as a single integrated unit although keeping their independence / autonomy. It also has to be taken into account that legacy systems were not designed with the idea of directly connecting to corresponding systems in other enterprises. Typically, enterprises pre-exist before they decide to join in an information sharing and exchange network. Consequently, every enterprise is autonomous, developed independently from other enterprises and uses distinct information management and control strategies that serve its own purposes. Thus the situation is extremely heterogeneous and requires adaptation of existing production planning and control systems (PPC) to electronic linking.

To support this environment and coping with the legacy systems in enterprises, PRODNET-II proposes, for each node of a VE network, an architecture where, among others, Advanced Co-ordination Functionalties address a few advanced co-ordination aspects: (i) Partners search and selection; and (ii) Integrated logistics decision support system. The logistics decision support system aims at providing the enterprise with “real-time” information about the current status of the orders in the involved enterprises.

In this work, the supply-chain co-ordination in the VE environment will be subject of deeper analysis. The system developed by UFSC for the management of distributed business process will be presented and some basic concepts for its definition and development will be detailed.

2 BUSINESS PROCESSES IN THE VIRTUAL ENTERPRISE ENVIRONMENT

The Virtual Enterprises must also deal with orders requests. In this case, these orders are named distributed business processes (DBP). A DBP is a dynamic and temporary set of “orders”
(business processes - BP) which jointly gives rise to the end product of the VE. As the BPs are supposed to be performed by several enterprises, the enterprise that triggered the formation of a given VE normally must co-ordinate their execution in order to avoid business chaos (Rabelo et al., 1996). In a VE scenario the management of the value-chain is a complex task, especially when some degrees of co-ordination are envisaged to be supported. Figure 1 illustrates a DBP concept via its production graph. The enterprise '2' (node 2) is currently the client-enterprise, whereas node-1, node-3 and node-5 are its direct suppliers. Each node has some (sub-) BPs under its responsibility (and so the respective Enterprise Activities - EAs), placed into the dashed circle around them. They represent the value added by each enterprise on the production chain, along the time. For example, node-1 has to perform four interdependent BPs (BP₁₁₀, BP₁₂₂, BP₁₂₂A and BP₁₂₂B), whose result has to be sent to node-2 so that the BP₁₁ can be done and so the whole production can be kept.

Since these BPs are supposed to be performed by several enterprises, the client-enterprise must manage their execution. As such, it is also liable to unexpected events, like BP delay, BP or DBP cancellation/modification, changes on DPB priorities as well as to local communication deficiency and network overloading or failure. When one of these problems occurs and the responsible enterprise cannot solve the problem locally, it offends the DBP contract, and then causes a conflict. This conflict basically influences the DBP production dates (the planned delivery date) and can affect the whole production chain. Because the components of a DBP are all inter-related, an enterprise cannot (re)plan itself for its own benefits only, but it must also look for the benefits of the whole net. Consequently, a close cooperation has to exist both intra-enterprise and inter-enterprises in order to minimize the global loss in the “DBP contract”.

The complexity of the resolution of a conflict may vary quite a lot. Because an enterprise usually plans with some temporal intervals between the BPs (just to absorb the unexpected occurrences), a re-planning negotiation may be relegated to adjust the planned delivery date either to the earliest delivery date or the latest delivery date. This policy could be one solution for a rapid contract re-negotiation and hence for a fast DBP plan re-establishment. However, depending on the problem severity, the solution may involve a deeper - and possibly complex - analysis. Many considerations and evaluations have to be taken into account, specially regarding that an enterprise usually does not have only one DBP contracted, but plenty of them, which in turn can be indirectly affected by the problematic BP. Thus, the whole complexity makes almost impossible a user or a system solve the problem individually. Neither a single user has all knowledge and enough capabilities (in terms of time and technical background) nor a system has the natural human ‘business flexibility’ and experience for good trade-off analysis / decisions.

In that sense, a balanced approach seems to be the suitable solution to contemplate the enterprise with these two ‘knowledge sources’ simultaneously. In other words, a DSS which can help and assist the user in a decision-making. In this context, a DSS has to cope with the following stages (O'Neill, 1995): identify the problem situation; data acquisition and analysis; determine causes of problem; define objectives; generate alternative solutions; comparing and evaluating alternative solutions; select (the ‘best’) solution.

A framework for this DSS must provide the decision-maker with selected information, describing both the competitive external environment and the way the enterprise is operating. Besides that, it must also provide well-established decision-making support models and techniques.

In that direction, the implemented DBPMS (Distributed Business Processes Management System) offers an enterprise with an environment that provides reliable and timely information about the supply-chain and a support for rapid decision-making, two extremely important enabler aspects to support the enterprise agility and hence its competitiveness.

3 AGILE COORDINATION

The co-ordination is a subject of great importance for the realization of a VE. Considering that the network of enterprises is formed due to the requirements of specific orders, there must be a way to co-ordinate these activities. In the Prodnet-II project this is made through “Advanced Co-ordination Functionalities” (ACF). ACFs correspond to specialized software modules being developed to help solving specific problems that require co-ordination actions within the VE.

The co-ordination functionalities are, in fact, a subset of the functional requirements for a VE. The Prodnet-II architecture and implemented platform comprises a number of semi-autonomous software modules that provides the enterprise with
several other functionalities, such as: exchange of commercial data (using EDI/EDIFACT and WWW), exchange of technical product data (STEP), quality related information exchange, VE information management, and incomplete and imprecise orders management. All these “services” are supported by other basic software modules to guarantee the privacy and safety communication, distributed data management, architecture / services configuration and global co-ordination among the modules (Camarinha-Matos &al., 1998).

From the enterprise point of view, all those functionalities are seen as a “black box” which offers VE services - the Prodnet Platform. It corresponds to an upper software layer to be installed on the “top of” enterprises' legacy systems (their internal modules) so that the enterprises can operate in a VE scenario in a “transparent” and integrated way. In fact, two main modules constitute this platform: the Prodnet Cooperation Layer (PCL) and the ACF modules.

The ACFs can be seen as high-level services to be offered to an enterprise/users and that uses the core services from the PCL’s modules. The communication between the ACFs and the PCL is supported by means of a specific (but open) API (Application Program Interface).

The DBPMS represents an ACF which aims to provide means for getting, analyzing, making available and managing the information from and about a VE, enabling the enterprises to make their logistics more efficiently by means of a integrated information-based supply-chain management. It was designed to act mainly in the operation phase of a VE life cycle (Spinoza &al., 1998b), comprising a bit of the creation/configuration and dissolution phases.

In fact, the main fundamentals of the implemented DBPMS functionalities reflect the consideration of the emergent and wider concept of logistics called “integrated logistics management” (Christopher, 1994). In that sense, the DBPMS extends the intra-organizational logistics carried out by the classical PPC systems, with a higher-level vision about the VE's logistics, giving rise to an inter-organizational logistics (Klen &al., 1998b). Its general approach is illustrated in the Figure 2.

![Figure 2: DBPMS General Approach](image)

The whole process starts when the VE-Coordinator (the VE trigger) wants to monitor, after a given VE is created, the processing of a certain BP at a given VE-Member’s site (a Supplier). During the VE creation phase a set of agreements is made, including the specification of a number of information that the VE-Member’s PPC should send to the VE-Coordinator (like order status, remaining process time, the amount of parts already produced, etc.) as well as the periodicity this should be made.

These specification are indicated in the “supervision clauses”, an innovative information structure logically aggregated to the respective BP’s contract (the “purchase order’s contract” in the PPCs), which is filled up by the user via a specific graphical interface. Supervision clauses are used to specify the VE-Coordinator and VE-Members’ rights and duties in terms of information access for monitoring purposes. In general, they specify what, how, when, where and how far a given set of information about an order should be monitored from each VE supplier.

Once a given VE is created, all the information about it - and the one required by the DBPMS – is stored into the Distributed Information Management System (DIMS). The information being monitored (specified in the rights of the VE-Coordinator) is sent and managed by DIMS – one of the PCL’s modules – which acts as federated and distributed database (Afsarmanesh &al., 1998), providing a “transparently”, secure and encrypted inter-communication between the VE-Coordinator and every VE-Member (Ostorio &al., 1998). Depending on the complexity of the transaction, another PCL’s module is invoked to better coordinate the PCL’s services workflow internally.

In the Prodnet-II approach, the VE-Members’ PPCs should obtain the set of duty information (in predefined cycles of time) from their shop floors and put them available in their respective DIMS, so that the VE-Coordinator’s DBPMS can have access to them in order to reason about. The continuous arrows in the figure 2 illustrate this flow.

In the other direction there are the rights of the VE-Member, or in other words, the duties of the VE-Coordinator. It is also important to endorse the suppliers with reliable information. In this sense, the VE-Coordinator may have to inform the VE-Member about a set of information, previously agreed and specified in the supervision clauses / duties. The dashed arrows in the figure 2 illustrate this flow. It means that a minimum set of DBPMS services should also be provided to the VE-Member side.
4 THE DBPMS FUNCTIONALITIES

The implemented DBPMS functionalities are comprised into three main blocks:

4.1 Supervision Clauses Configuration

It allows the user to interactively configure the supervision clauses to be applied upon every VE-Member of a given VE. It comprises the mapping between the VE-Members' PPCs capabilities in terms of information gathering against the DBPMS needs, and also the set of (different) clauses at the levels of requested / purchase orders, required items and production orders.

4.2 VE Supervision

One of the main problems the enterprises face nowadays is the difficulty for obtaining reliable information from the partners about the real status of some contracted BPs, which directly affect the DBP (the entire client order). This situation obliges the enterprises to frequently re-plan their actions due to the occurrence of unexpected events, representing in delays or anticipations. It means an increasing of the enterprise's global costs because a delay or anticipation of one supplier can affect the execution of other inter-related BPs. This functional block aims to offer an electronic way to get information from the suppliers so that the enterprises can constantly update their production plans and schedules (Rabelo &al., 1997).

4.3 Decision Support System (DSS)

The introduction of a decision-support system (DSS) that helps an enterprise to evaluate and to decide in the presence of a conflict is a key point for its efficient reaction. This kind of system can play its role much better if it is fed with reliable and real-time information from the supply-chain, which is provided by the functionality previously explained. It incorporates analytical procedures as a support for the VE (re)scheduling and its evaluation, including means for a trade-off analysis (Spinosa &al., 1998a) (Rabelo &al., 1998). This DSS assumes a strong interaction with the enterprises' end-users.

Figure 3 illustrates the implemented DBPMS architecture, involving seven main modules to which the user can interact with:

- Supervision Clauses Configuration: configuration of the rights and duties of the VE-Coordinator and VE-Members of a given VE;
- DBP monitoring: real-time information gathering from the suppliers’ PPCs (in terms of orders);
- Conflict detection: detection and identification of unexpected problems during the orders processing;
- Reactive decision-making: support for a decision-making according to the conflict detected;
- Simulation & assessment of alternatives: support for the selection of a simulated decision by the user;
- VE Analyzer: has the objective to provide an intra-organizational analysis of the VE in operation as well as an inter-organizational analysis of the alternative solutions.
- DBP Control: set of actions that should be carried out in order to implement a selected (simulated) decision.

In fact, those functionalities represent a subset of a wider functional requirement analysis, which was supported by a specific methodology (Klen &al., 1998a) and that had three main inputs: a research made in the literature; a specific questionnaire conceived and sent to other research projects; and the consideration of the end-users needs by means of the application of another methodology also especially conceived for knowledge acquisition.

Taking the main DBPMS modules into account, figure 4 illustrates one of the graphical interfaces of the Simulation of Alternatives module. The DBPMS is implemented in C++, running on a PC / Windows-NT / TCP/IP platform.

5 MODELLING THE DISTRIBUTED BUSINESS PROCESS

For the system development, one of the important steps was the modeling of the Distributed Business Process (DBP). From the DBPMS point of view, a DBP is an object-oriented information structure that models the VE’s goal, i.e. the final “product” in the Prodnet-II ontology. It was designed in order to fulfill the DBPMS requirements in a VE scenario. In a real case, the DBP concept encapsulates all the suppliers, all the orders and operations, among other information, involved in a given VE. It differs from the traditional information that is managed by an enterprise, which stores information (via the Prodnet's...
EDI/PPC modules) about its supplier and customer orders, but anything about its "production orders" as required by the DBPMS, i.e. about what it should do / produce for a given DBP / VE.

Figure 4: An example of how alternative solutions are showed.

The DBP structure was designed taking some concepts of the CIM-OSA project into account (AMICE, 1993). In this sense, a DBP is a hierarchical model, composed by the basic entities showed in figure 5. Regarding the usual lack of terminology standards in the production domain, the DBP modeling / specification was strongly based on the dictionary elaborated by the American Production & Inventory Control Society (APICS, 1983).

Figure 5: DBP model general structure.

The Distributed Business Process Management System (DBPMS), a system that intends to "implement" the emergent concepts of Supply-Chain Management / Integrated Logistics Management.

The system is modular, comprising basically three main interactive and cooperative modules: Supervision Clauses Configuration (to specify the rights and duties of the VE participants from the information monitoring point of view), VE Supervisor (to monitor the DBP execution) and DSS (a Decision Support System to help the user in the decision-making process based on the information obtained by the VE Supervisor).

It should be noted that the DBPMS, once providing some scheduling capabilities for conflict solving, can offer some support to keep a "DRP" (distributed requirements planning) coherent during the execution of a given DBP and hence can be seen as a powerful module for an ERP (enterprise resources planning).

Additionally, it is important to point out that, considering: (i) the DBPMS complexity, (ii) the innovative aspects being investigated, and (iii) the open questions still presented in the VE paradigm; the experiments exploited by the DBPMS module have their scope and scenarios limited and tested only in the Prodnet-II (homogeneous) platforms. In terms of functionalities, they have been oriented to the demonstration pilot prototype (but using real data e situations), even because it is still not clear the possible overlapping between some "future" PPC functionalities and those ones the DBPMS should have.

6 CONCLUSIONS

All the literature researched and the conceptual work presented in this work was actually motivated by the need to identify some advanced coordination functionalities (ACFs) in order to try to avoid the business chaos when coordinating one or more DBPs of a VE.

One of the identified and implemented ACFs is the Distributed Business Process Management, which aims to support means to get, provide, and to manage the information from and about a VE, enabling the enterprises to make their logistics more efficiently in an integrated way. This ACF is represented by the

Distributed Business Process Management System (DBPMS), a system that intends to "implement" the emergent concepts of Supply-Chain Management / Integrated Logistics Management.

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