8

FOR A SMART COORDINATION OF DISTRIBUTED BUSINESS PROCESSES

Ricardo J. Rabelo [1]; Alexandra P. Klen [2]; Aureo C. Ferreira [2]
[1] *Federal University of Santa Catarina, Department of Automation and Systems, Brazil*
rabelo@das.ufsc.br
[2] *Federal University of Santa Catarina, Department of Mechanical Engineering, Brazil*
{klen;ferreira}@gsigma-grucon.ufsc.br

This work addresses the supply-chain coordination in the virtual enterprise environment, pointing out a system developed in the scope of the ESPRIT Prodnet-II project to provide an advanced functionality to manage distributed business processes at the operational level. A wider system architecture being investigated to provide a smart functionality to manage a dynamic supply chain network is focused. In this new architecture, other and complementary technologies not used in the Prodnet-II project are being applied, namely Multi-agent Systems, CORBA and WWW. At the advanced functionality level, the system provides means for getting, analyzing, making available and managing the information from and about a virtual enterprise, enabling the enterprises to make their operation more efficiently by means of a integrated information-based supply-chain management.

1. INTRODUCTION

In the manufacturing sector, the Virtual Enterprise (VE) is mostly composed of small and medium-sized enterprises behaving as suppliers and having no definite relations, policies and implications. Thus 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 order request of a VE, in this case called distributed business process (DBP), is a dynamic and temporary set of 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, there must be a way to co-ordinate these activities in order to avoid business chaos, guaranteeing the VE's goal accomplishment. In such a virtual scenario, the supply chain management is a complex task, especially when some degrees of coordination are envisaged to be supported. This paper will address two of these coordination levels: the advanced coordination and the smart co-ordination. The former will be presented making use of the experience acquired and the system developed within the Prodnet-II Esprit project (*Production Planning and Management in an Extended Enterprise*) (Prodnet, 99). The latter will be introduced taking into account the current research being carried out in the scope of the recently started IST DAMASCOS project (*Dynamic Forecast for Master Production*

Planning with Stock and Capacity Constraints) by the Federal University of Santa Catarina (UFSC) (DAMASCOS, 00)[i].

Whereas in Prodnet-II scenario individual issues of parts of the supply chain were focused, in this new research this scope is extended to cope with other aspects, acting as an integrator / holistic functionality, then providing a smarter way of coordinating the supply chain. The main goal of both systems is to focus on the possibilities of getting, analyzing, making available and managing the information from and about a VE as well as enabling the enterprises to make their logistics more efficiently.

In this sense, this work will firstly present the "Distributed Business Process Management System" (DBPMS), highlighting its general approach as well as its main functionalities and modules. Secondly, the main lines of a system called as "Supply Chain Smart Coordination" (SC^2) will be introduced. Finally, some considerations will be made regarding that the current main supporting information technologies used in the DBPMS framework are being changed in order to attend the new requirements for smart coordination. In fact, the new technologies – namely Multi-agent Systems, CORBA and WWW – have been investigated to evaluate how they can improve or complement some aspects of the Prodnet-II platform in the context of the DBPMS / distributed business processes management.

2. COORDINATING DBP

A VE must also deal with order requests. In this case, these orders are known as distributed business processes (DBP). A DBP is a dynamic and temporary set of business processes (BP) which jointly gives rise to the end product of the VE. As the BPs are supposed to be performed by various enterprises, the enterprise that triggered the creation of a given VE normally co-ordinates its operation in order to avoid business chaos (Rabelo et al., 96).

The coordination is therefore a subject of great importance for the realization of VEs. 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. Therefore, the idea is to extend the intra-organizational logistics carried out by the classical ERP systems with a higher level vision of the Virtual Enterprise's (VE) logistics, giving rise to an inter-organizational logistics. Since the use of information technology is being encouraged increasingly for sharing and exchanging information among individuals and organizations in different places, this trend is here understood as a consequence of a new strategy of conducting business, which is the concept of Virtual Enterprises (VE).

2.1 Advanced Coordination and the DBPM System

According to the Prodnet-II project, a virtual enterprise is seen as a temporary alliance of enterprises that come together to share skills and resources in order to better respond to business opportunities and whose co-operation is supported by computer networks and adequate IT tools and protocols (Camarinha-Matos et al., 99a). The services offered by the Prodnet-II Platform correspond to an upper layer of software to be installed in the enterprise legacy systems (their *internal modules*) so that the enterprises can operate in a VE scenario in a "transparent" and integrated

way. In fact, this platform comprises two main modules: the *Prodnet Cooperation Layer* (PCL) and the *Advanced Coordination Functionalities* (ACF) *modules* represented by the DBPM system. The ACFs are seen as high-level services to be offered to an enterprise to help solve specific problems that require coordinated actions at the VE level. The communication between the ACFs and the PCL is supported by means of a specific API (*Application Program Interface*).

The essential objective of the developed ACF DBPMS (*Distributed Business Process Management System*) is to offer an enterprise with an environment that provides reliable and timely information about the production supply-chain (the main enterprise and its suppliers) and a support for rapid decision-making, two extremely important enabling aspects to support the agility of the enterprise and hence its competitiveness. In general, it makes orders follow-up, mainly acting in the operation phase of a *VE life cycle* (Klen et al., 99).

The orders follow-up is performed based on the specification of a number of information items 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 how often this should be done. These specifications are indicated in the so called "supervision clauses", an information structure aggregated to the respective BP contract (Rabelo at al., 99). Once a given VE is created, all the information about it – and that one required by the DBPMS – is stored in a system responsible for the management of distributed information (DIMS) (Afsarmanesh et al., 98), and fed by the VE-Coordinator's ERP (Camarinha et al., 99b). Prodnet-II platform allows a "transparently" inter-communication among the VE nodes by means of using the DIMS' services (FQP) as a federated and distributed database, which in turn involves a secure and encrypted information flow between the VE-Coordinator and the VE-Members (Osório et al., 98).

2.2 DBPMS Main Functionalities

Four main blocks defines the DBPMS (figure 2):

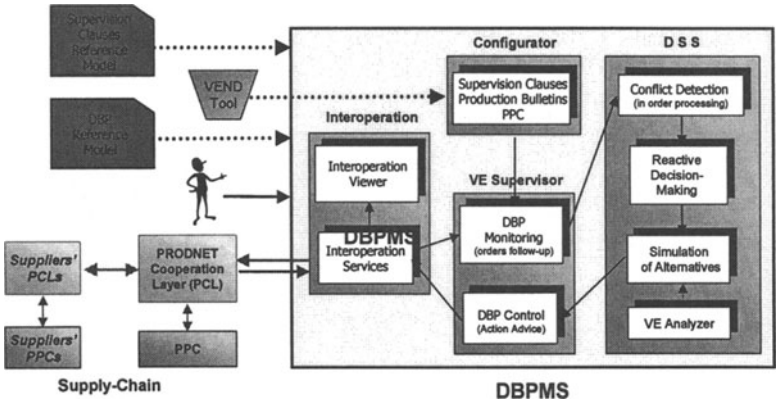

Figure 2 – DBPMS Architecture

- VE Supervisor: This functional block aims to offer an electronic way to get information from the suppliers – based on the DBP reference model – so that the

enterprises can constantly update their production plans and schedules. Besides that, it provides important advises to VE members when coordination actions are applied. It is composed by two modules, which get information from the suppliers' ERPs, and set actions that should be carried out to implement a selected decision.

- Decision-Support for Logistics Management (DSS): It aims at helping an enterprise to evaluate and to decide in the presence of a conflict in the supply chain. It is composed by four modules that: detect a problems in the orders processing, support a decision-making according to the conflict detected, support for the selection of a simulated decision by the user; and that provides an intra-organizational analysis of the VE in operation as well as an inter-organizational analysis of the alternative solutions.
- Configurator: It allows the user to interactively configure the DBPMS. It involves the configuration of the Supervision Clauses to be applied upon every VE-Member of a given VE (according to the VE Network Directory - VEND), the mapping between the VE-Members' PPCs capabilities in terms of information gathering against the DBPMS needs, and the configuration of production bulletins.
- Interoperation: It gives the support for the interoperation between the DBPMS and the other Prodnet's modules (Prodnet Cooperation Layer). It is composed of two modules: one containing the services to guarantee the DBPMS interoperation with the other Prodnet modules, and a browser that allows the user to monitor the interactions between the DBPMS and the other modules.

Figures 3 shows an example of a graphical interface provided by the DBPMS with the simulation of alternatives related with a given VE composed of four suppliers, each one responsible for the execution of a specific BP.

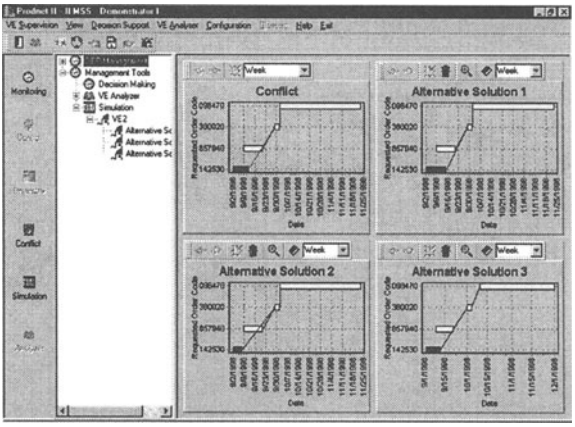

Figure 3 – Simulation of Alternatives user interface

2.3 Supervision Clauses Configuration

Supervision Clauses correspond to one of the most important reference models for the DBPMS realization. They are an information model logically aggregated to the

contract model and are necessary among the VE-Coordinator and Members. It complements the "traditional" contract. In general, supervision clauses specify *what* and *how* a given set of information (production dates, quantities produced, order status, production bulletins to a client, etc.) about an order from a given supplier should be monitored, i.e. they are used to specify rights and obligations in terms of information access for monitoring purposes. The DBPMS offers a supporting module for configuring the supervision clauses.

3. SMART COORDINATION

The answers found in the Prodnet-II project through the development of DBPMS served to raise a new set of questions that also lead us to conclude that the next step of the *Advanced Coordination* will go in the direction of *Smart Coordination.* According to (Filos, 99), Smart Organization is represented by a business environment in which clusters of inter-networked organizations collaborate around a particular technology and make use of a common architecture to deliver independent elements of value that grows with the number of participating organizations.

Considering that a dynamic supply chain in consumer goods industries typically involves the coordination of small firms at the production and distribution/sales levels, supervision tasks are, at these levels, considered as *advanced* coordination functionalities (ACF), as did in Prodnet-II project. In a further stage, taking into account that the chains are normally coordinated and initiated by the consumers goods (principal) producer as the central part of the chain, it is also necessary to extend those functionalities to a higher level, where the *smart* coordination functionalities (SCF) are placed. While the former focuses restrict/individual issues of parts of the supply chain at the operational layer, the latter considers the dynamic supply network layer, acting as an integrator/holistic functionality, considering the *whole* dynamic supply chain, involving the production, distribution and sales chains.

The set of Advanced and Smart Coordination Functionalities composes the "Supply Chain Smart Coordination" System (SC^2) that is being developed (figure 4).

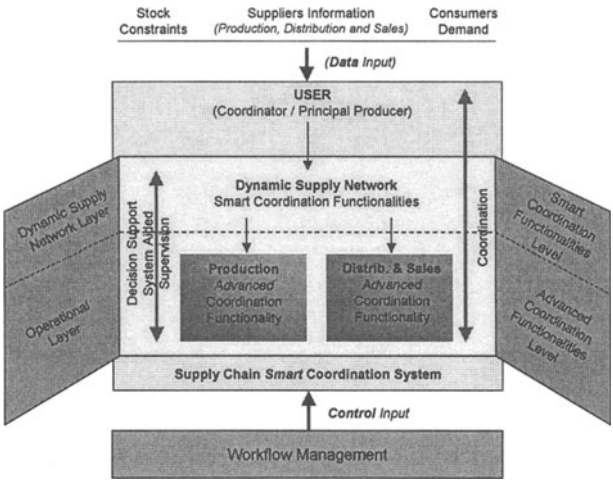

Figure 4 - Supply Chain Smart Coordination Module Framework

The Production ACF corresponds to the DBPMS system, already developed but that should have some of its basic supporting information technologies modified to attend the requirements of the SC^2 framework. The SC^2 system aims at providing the user/principal producer with a decision support system in order to manage a wider perspective of the supply chain comprising not only production but rather distribution and sales as well. Besides being able to assess the dynamic supply chain from an upper level – and not only via individual views – the SC^2 system will also receive input data from forecasting, considering stocks and capacities constraints, being coordinated by a workflow backbone / module. The coordination aspects will then be seen as a hierarchical approach, comprising: i) Workflow backbone, as a low coordination view; ii) Advanced Coordination Functionalities, as a middle coordination view; and iii) Smart Coordination Functionalities, as a high coordination view.

4. COMBINING MULTIPLES TECHNOLOGIES FOR SMART COORDINATION

In the previous development, DBPMS was implemented as a monolithic decision support system and whose access to information about the virtual enterprise and its members was supported (only) by a proprietary set of FPQ services. Based on the experience with Prodnet-II, it was observed that the general DBPMS / SC^2 framework could be improved with the application if other complementary technologies: Multiagent Systems, CORBA and WWW.

4.1 Multiagent Systems

The Multi-Agent System (MAS) technology has emerged as a powerful technology to support a cooperative resolution of distributed problems, presenting several advantages compared with monolithic architectures (Jennings, 94). In general, A MAS system corresponds to a network of problem solvers that work together to solve problems that are beyond their individual capabilities.

In the case of the SC^2 system, the main value-added with the adoption of a MAS approach is the supporting of subsystems cooperation, autonomy, decentralized decision-making with flexible constraints relaxation, and the integration of (different and specialized) knowledge sources and heterogeneous/distributed subsystems in the same environment. The SC^2 system is composed of three agents, two ones for two ACFs and one for the SCF. Besides that, the adaptations in the DBPMS for the SC^2 framework will imply that each of the four main DBPMS blocks will be represented by an agent. A particular high-level protocol to support the agents cooperation and coordination should be also developed although it is not a difficult task regarding the previous experience with other projects, such as MASSYVE (Massyve, 98).

4.2 CORBA

The *Common Object Request Broker Architecture* (CORBA) is the Object Management Group's answer to the need for interoperability among the rapidly proliferating number of hardware and software products available today. Simply

stated, CORBA allows applications to communicate with one another no matter where they are located or who has designed them.

Of the most important CORBA components is ORB (*Object Request Broker*). ORB is the middleware that establishes the client-server relationships between objects. Using an ORB, a client can transparently invoke a method on a server object, which can be on the same machine or across a network. ORB provides interoperability between applications on different machines in heterogeneous distributed environments and seamlessly interconnects multiple object systems. Considering the Windows-NT environment and that the DBPMS was developed in C++, the tests with CORBA have been made with the ORB VisiBroker.

In the case of the SC^2 system, there are two mains value-added expected with the adoption of a CORBA approach. The first one is that CORBA is platform-independent, allowing SC^2 to interoperate with other applications in other platforms transparently. Via ORB, the applications' objects can be found "automatically" and the respective methods accessed wherever they are. The second facility is that all the information is accessed as *objects* and not as structures. It is important for the DBPMS regarding that in the previous implementation with the Prodnet DIMS module the information exchanged among them was made using complex structures, most of them very difficult to be managed. The preliminary tests to be made will use the MS Access Database with a CORBA layer / server on the top of it.

4.3 WWW

The use of the World Wide Web (WWW) technology has been increasingly used by the enterprises nowadays, both to make business and as a way to share information with their employees, consumers and suppliers. It is a "reality" that cannot be neglected in modern systems. As it was mentioned before, the current DBPMS implementation had access to information about the VE-Members only via a *distributed/federated database query mechanism* (FQP) services. However, in the DBPMS context, it was realized that the access to some kind of information in some situations could be more efficiently made by means of using a Web-Server, supported by the HTTP (*Hypertext Transfer Protocol*).

A Web-Server receives a client request and can perform any number of actions, based on its configuration. The client receives the answer as an HTML file, easily parsed internally by the client application. The internal "organization" and content of that HTML file depends on how the involved Web-Server's application program is implemented to perform the client request.

In the context of the DBPMS/SC^2 system, in spite of other existing technologies such as Internet Express and MIDAS, the tests were implemented using DLLs. In another level, next experiments will involve the use of XML.

4.4 The New SC^2 Framework

After all those three technologies have been generally described and their application in the SC^2 context has been explained, the figure 5 below illustrates in general how they are integrated in the proposed architecture. For a better comprehension, the several other possible modules in both hypothetical enterprises,

both within the "VE Cooperation Layer" (like the workflow and security systems) and the enterprise's internal modules are not included in the picture.

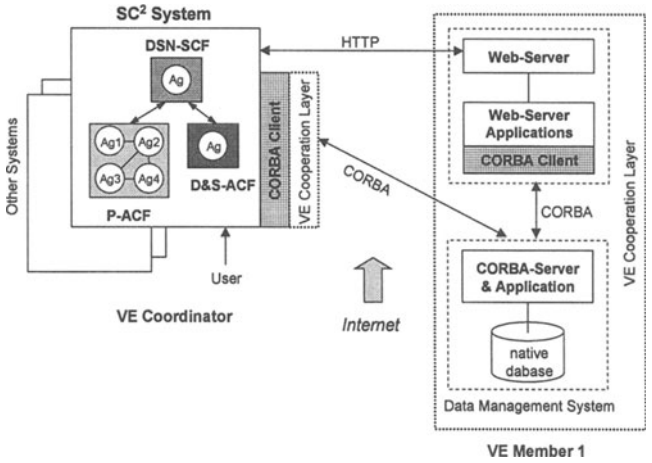

Figure 5 – SC² Global Architecture

In order to let it more clear, let us limit the scenario with an example focused on the SC²'s Production module (P-ACF) – the modified DBPMS system. Suppose a VE-Member (a supplier) that wants to know from the VE-Coordinator (the principal producer in a dynamic supply chain network) the general execution status of a predecessor BP that was assigned to a given enterprise. It is useful for it in the sense that it can also be aware about a problem in the supply chain and then can prepare itself for eventual replanning. Once a VE is created, it is configured. This configuration implies in the definition of roles, the BPs to be performed by each VE-Member, the information access rights, among other "instantiations". Besides the other services offered by the VE platform, the Web-Servers of each enterprise are programmed in the sense that their web-server-applications are also prepared to receive requests from other enterprises. During the VE operation phase, the requests can be made through two ways, depending on the needs.

The first way is accessing a given enterprise database via CORBA(-server), in a similar way of the DBPMS does in Prodnet. It means that the same Prodnet's philosophy could keep being used, i.e. the initial configuration data to be stored about a VE as whole can be made via DBPMS → CORBA-Server / database. This way is more suitable when complex information structures need to be exchanged.

The second way takes place during the VE operation phase, mainly. In the supervision task of the Prodnet scenario, the DBPMS installed at the VE-Coordinator side makes periodic requests to a given VE-Member's ERP in order to get the information previously indicated in the supervision clauses. In the SC² framework, besides supporting this situation, a VE-member is also provided with capabilities to request information (and other functionalities), as said before. The difference is that now a request is made via HTTP, directly to the desired VE-Coordinator's Web-Server, and vice-versa. The invoked application is triggered, the requested information is obtained from the database (via the CORBA-Server) and

the data is returned as an HTML file. Dealing with HTML files in not a problem, even because the "original" DBPMS already treats files like that when periodic production bulletins are generated and sent to the VE-client. This way is more suitable when relatively simple information structures need to be exchanged.

5. CONCLUSIONS

This paper presented an approach for managing distributed business processes in dynamic supply chain networks. In that sense, two hierarchical levels of coordination are applied at the Virtual Enterprise (VE) plane. At the lower level, the advanced coordination functionalities (ACF) focus on restrict/individual issues of parts of the supply chain, whereas at the higher level the smart coordination functionalities (SCF) level focus on a global view of the supply chain behavior, hence acting as an integrator of the advanced coordination functionalities.

This current research is strongly based on the results and experiences gained with the development of the DBPMS system, an advanced coordination functionality developed in the scope of the Esprit Prodnet-II project. The DBPMS is a knowledge-based decision support system that provides means for obtaining, analyzing, making available and managing the information from and about a VE, enabling the enterprises to perform their operation more efficiently.

Another part of this work addresses an evolution of the DBPMS framework in order to cope with the new requirements of smart organizations and their general coordination in a Virtual Enterprise scenario. Thus, the main lines of a new system called as "Supply Chain Smart Coordination" (SC^2) are introduced. The SC^2 system aims at providing the user/principal producer with a decision support system able to manage a wider perspective of the supply chain comprising not only production but rather and distribution and sales as well, considering stocks and capacities constraints detected by a forecasting module.

An architecture for the SC^2 system was presented, comprising three coordination functionalities: the Production ACF and the Sales & Distribution ACF, and the Dynamic Supply Network SCF. The Production ACF corresponds to the DBPMS system, already developed but with some new basic supporting information technologies – namely Multiagent Systems, CORBA and WWW. The workflow and security systems were not considered in the phase. The experiments made with these new technologies are still preliminary and more tests are needed. However, some conclusions can be initially mentioned. The integration of different technologies and some *standards* within the same environment resulted in a relatively complex architecture. Nevertheless, it is feasible and its general functioning occurred without significant problems, or at least less than it was initially expected. In fact, the complexity brought to the architecture with the introduction of those technologies seems to be compensated with other benefits.

The "agentification" of the DBPMS improves several capabilities of the previous implementation. The cooperation framework is more consistent, the autonomy and decentralized decision-making abilities are augmented, flexible constraints relaxation can be achieved in a more efficient way, and specialized knowledge sources/distributed subsystems can be integrated in the same environment.

CORBA is platform-independent, allowing SC^2 to interoperate with other applications in other platforms transparently. Via ORB, the applications' objects can be found "automatically" and the respective methods accessed wherever they are. All the information is accessed as *objects* and not as complex structures.

A Web-Server based approach seems to be more suitable when relatively simple information structures need to be exchanged (compared with a direct access a (CORBA) database (VE information management system). The need to develop access functions is an intrinsic task and it can be said that it correspond to the same task that should be developed for a VE database server. An open point here is how a WWW / HTTP solution can make difficult the coordination of a VE platform that is tightly coordinated by a workflow system.

5. ACKNOWLEDGMENTS

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6. REFERENCES

1. Afsarmanesh, H.; Garita, C.; Hertzberger, L.O. (1998), *Virtual Enterprises and Federated Information Sharing*, in Proceedings of the 9th IEEE International Conference on "Database and Expert Systems Applications", DEXA'98, Lecture Notes in Computer Science, Vienna, Austria.
2. Camarinha-Matos, L.M.; Afsarmanesh, H. (1999a), *The Prodnet Goals and Approach*, in Proceedings of the Working Conference on Infrastructures for Virtual Enterprise (PRO-VE'99), October 27-28, 1999, Porto, Portugal.
3. Camarinha-Matos, L.M.; Santos-Silva, V.; Rabelo, R. J. (1999b), *Production Planning and Control in a Virtual Enterprise*, in Proceedings of the Working Conference on Infrastructures for Virtual Enterprise (PRO-VE'99), October 27-28, 1999, Porto, Portugal.
4. DAMASCOS (2000) http://www.damascos.com.
5. Filos, E., *Virtual Organisations, Business Networks & the 5th Framework Programme* (1999), Invited Speech of the Working Conference on Infrastructures for Virtual Enterprise (PRO-VE'99), October 27-28, Porto, Portugal.
6. Jennings, N. (1994), *Cooperation in Industrial Multi-Agent Systems*, World Scientific Series in Computer Science (Vol 43), 1994.
7. Klen, A. P.; Rabelo, R.J.; Spinosa, L.M.; Ferreira, A. C. (1999), *Distributed Business Process Management*, in Proceedings of the Working Conference on Infrastructures for Virtual Enterprise (PRO-VE'99), October 27-28, 1999, Porto, Portugal.
8. MASSYVE (1999) http://centaurus.dee.fct.unl.pt/~massyve.
9. Osorio, A. L.; Gibon, P.; Barata, M. (1998), *Secure electronic commerce in virtual enterprises of SMEs*, in Intelligent Systems for Manufacturing – Multi-Agent Systems and Virtual Organizations, Eds. Luis M. Camarinha-Matos, Hamideh Afsarmanesh and Vladimir Marik, Kluwer Academic Publishers, pp. 207-218.
10. PRODNET (1999) http://www.uninova.pt/~prodnet
11. Rabelo, R. J.; Camarinha-Matos, L. M. (1996), *Towards Agile Scheduling in Extended Enterprise*, em "Balanced Automation Systems II - Implementation Challenges for Anthropocentric Manufacturing", Eds. Luis M. Camarinha-Matos and Hamideh Afsarmanesh, Chapman & Hall.
12. Rabelo, R. J.; Klen, A. P.; Spinosa, L.M.; Ferreira, A. C. (1999), *Agile Supply-Chain Coordination in the Virtual Enterprise Environment*, Proceedings 4th IFAC/IFSA Brazilian Symposium on Intelligent Automation – SBAI'99, São Paulo, Brazil.

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[i] DAMASCOS partners are: INESC-Porto (PT), INTERFACE (G), SMD/PARAREDE (PT), SICS (SW), NMA (SW), ATECA (IT), KYAIA (PT) and UFSC (BR).