35 INFRASTRUCTURES FOR VE: A SUMMARY OF ACHIEVEMENTS

L. M. Camarinha-Matos[1]*, H. Afsarmanesh[2]
[1]New University of Lisbon, Portugal
[2]University of Amsterdam, The Netherlands

A large number of national and international research projects in the virtual enterprise area have been devoted to the design and development of infrastructures and basic VE support functionalities. PRODNET II is an example of project that has contributed with substantial advances for an open and flexible infrastructure. Results from several other projects are also summarized, giving a brief perspective of the state-of-the-art in this area.

INTRODUCTION

Most of the development efforts in the area of industrial virtual enterprises (VE) have been concentrated on the design and development of infrastructures and basic VE support functionalities. Regarding the life cycle of the VE it can be noticed that most works have targeted the operation phase, while the creation phase although partially addressed by some projects, is still under-developed. Similarly, for the dissolution phase, very limited work has been done.

The VE infrastructure design activities have been carried out mostly in consortia involving the industry and academia. This is the case both at the national level such as the USA NIIIP project or the international level such as the Esprit PRODNET II, VEGA, and many other projects funded by the European Union, or the inter-continental IMS initiative, as exemplified by the GLOBEMAN 21 project. With less funds but also featuring the international cooperation are the INCO and ALFA programs, both funded by the European Union, where the VE related projects can also be found such as, for instance, the MASSYVE, SCM+, and COSME-VE. Complementarily, there are many other smaller initiatives at the national level in various countries. As such, the VE and virtual organizations represent today a major research field.

* Corresponding author address: Universidade Nova de Lisboa, Quinta da Torre, 2825 Monte Caparica, Portugal, tel. +351-1-2948517, fax +351-1-2941253, e-mail: cam@uninova.pt.

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As the outcome of these efforts, considerable amount of results have been achieved, where in fact with many features and approaches are common among different projects. Nevertheless many open issues remain that still require further work.

In addition to these developments on the infrastructure side, other areas of activity are becoming progressively more relevant. Among others, the distributed business process modeling, definition of new management and socio-organizational approaches, contracts modeling and management, standard information integration and exchange among legacy and heterogeneous information sources, definition of performance metrics, etc. can be mentioned. Next sections present a brief summary of the main achievements in PRODNET II and other relevant projects.

MAIN ACHIEVEMENTS IN PRODNET II

Global Achievements. The PRODNET II project succeeded in developing an open infrastructure that addresses a wide range of requirements set by the VE paradigm, with particular focus on the characteristics of SMEs.

Important features include: 1) support for safe communications, 2) guarantee of information privacy and configurable levels of information visibility, 3) interoperability between the EDIFACT and STEP standards, 4) identification and development of necessary extensions to legacy systems such as the PPC, in order to operate in a VE environment, 5) support for quality-related information exchange, and 6) VE task coordination management through the federated queries, for instance, for the follow up of orders status. Configurability and flexibility are major requirements for any VE-support infrastructure, what represented two of the main design criteria for the PRODNET architecture. In particular, the workflow-based hierarchical coordination approach developed by PRODNET II seems particularly adapted to these requirements. In terms of advanced coordination mechanisms, PRODNET II contributed to the areas of electronic search of partners and distributed business process management supported by an innovative federated information management approach.

Although most of these features were implemented at prototype level, they were demonstrated and validated by a complex demonstration scenario involving VEs with some companies in Europe and some in Brazil.

Achievements in Coordination. Similar to other projects, PRODNET II adopted a workflow-based approach for coordination. Combined with a graphical specification language and a graphical editor, LCM (Local Coordination Module) and LCF (Local Configuration Functionality) proved to be an efficient way to implement flexible, easily re-configurable, coordination strategies. Therefore, the needs of different companies and different business processes can be easily accommodated.

Other relevant aspects of the LCM and LCF modules are:

-The hierarchical coordination approach, considering the coordination problem at

different levels of abstraction, is a unique and innovative aspect. Three levels were considered in the developed architecture: core coordination, enterprise (VE member) level coordination, and VE level coordination.
-Extended mechanisms associated to the workflow engine such as temporized and cyclic activities, support high-level coordination needs such as contract clauses monitoring.
-A very tight integration of coordination and federated information management provides a sound basis for advanced VE coordination.
-A flexible "relevant data" management mechanism associated to the workflow plan activation offers a flexible support for the invocation of external services. This feature combined with a flexible configuration of both the external services and their input / output parameters, allows an easy addition of new functionalities (or removal of unused modules).

Achievements in Information Management. Information management in the PRODNET infrastructure is supported by the federated information management paradigm. Federated databases for DIMS have proven to provide particularly attractive features for handling some open-issues in management of information for the virtual organization domain, including:
- The federated database architecture of the DIMS has been specifically tailored to handle the complex interoperability and information management functionality requirements, that are identified in PRODNET II for the VE paradigm, such as the cooperative information sharing and exchange, node autonomy, information visibility levels, and access privileges for a wide variety of kinds of exchanged data among VE nodes.
- One novel feature of the DIMS approach is its unique architecture, in which the "PCL schema" is shared by all nodes but the data is imported/exported from its source at the query time according to the proper access privileges defined in the hierarchy of export schemas for VE partners. Consequently, the up-to-date data is always accessed by queries.
- The DIMS approach avoids the need for centralization of data and control over the VE nodes. Therefore, there is no need to handle the "data update" problems.
- The management of a hierarchy of export schemas by DIMS, supports the definition of information access rights for other enterprises, based on the existing legal contracts among the VE partner enterprises, and hence provides the configurability of the information access among enterprises.
- The federated query processing of DIMS is responsible for provision of access to the privileged proprietary VE information for which an enterprise is authorized simultaneously from several other enterprises, while hiding the data location details from the end user. The data access is performed against the data defined by export schema hierarchy management.

DBPMS main Achievements. The distributed business process management represents an advanced coordination functionality that illustrates part of the activities

to be supported by a VE coordinator. The developed prototype has the following main features:

-Orders follow-up along the supply-chain, based on the "supervision clauses" associated with the BPs (orders) contracts.

-Interactive support for conflict analysis and resolution in the order processing, via reactive decisions and simulations.

-Configuration for each particular enterprise (the way it operates).

-General support for Distributed Requirements Planning (DRP), since basic VE scheduling actions are provided.

-Integration with the PRODNET Cooperation Layer (PCL), namely with DIMS and LCM.

Achievements in Communications. The PRODNET communication infrastructure (PCI) offers to the enterprise applications a transparent access to a diversified set of communication resources, increasing availability and reducing communication costs. The main features of this module are:

- Message privacy, message integrity and enterprise/users authentication is guaranteed for the communication between different enterprises based on open communication resources from the Internet and ISO/ITU protocols suit.
- The communication infrastructure incorporates an advanced communication management function with communication resource selection based on a set of heuristics, aiming to establish the best selection from the installed communication resources, according to the specificity of the message to be delivered.
- The exchanged messages can range from a simple data buffer to a list of files of any type. The message is delivered according to the specified service quality and a receipt is generated to guarantee message reception commitment. Message attached files can be ciphered and signed.
- A monitoring access interface is provided to enable managers to make configuration tasks and to access logged information for auditing or diagnosis of exceptions.
- The communication infrastructure is able to receive and deliver unstructured messages through e-mail. This facility enables the integration of legated systems providing an open mechanism to deliver and receive messages from them.
- Authentication is based on the X509 standard version 3. The adoption of the standard facilitates for the interoperation between PRODNET and other certification frameworks, namely those established at a governmental level.
- A Web proxy extends the connectivity to a PRODNET infrastructure from any client with a standard Web browser. A special authentication mechanism, based on standard certificates, is the basis for the definition of the access rights, which depend on the authentication credibility presented by the Web client.

Achievements in EDI. The EDI module integrated in the PRODNET architecture allows VE members to exchange business information based on the EDIFACT standard. Some important features of this component are:

-The graphical EDI subset editor that allows a fast mapping design of the particular subset of messages to be used between every two partners as well as the graphical design of the format of each message (selection of fields). This editor allows a considerable reduction in the set up time necessary to make two enterprises able to interchange EDIFACT messages.

-The EDI subsystem is fully integrated with the other components of the architecture, namely the DIMS, PCI and LCM, providing a library of services that are used by the workflow coordination system.

Achievements in STEP. The STEP component of PRODNET allows for the exchange of technical product data. The main aspects of this module are:

-Integration of STEP and EDIFACT through the CONDRA message.

-Integration with the other components of the PRODNET architecture, namely the DIMS, PCI and LCM.

-Integration with other applications such as a PDM Editor for viewing and editing product organizational information, and a viewer for visualization of geometric product data.

Achievements in VE Creation and Configuration. Although PRODNET is more focused on the VE operation phase, some results were achieved for the creation and (re-) configuration phase:

-Identification and characterization of the main steps in VE initialization and configuration.

-Implementation of a set of tools to configure the main aspects of the architecture in order to tailor it to the particular operating conditions desired for each VE.

-Tool for partners search and selection based on real suppliers' directories available on the Internet. This tool gives some perspectives on the direction of a multi-step negotiation process during the partners' selection phase.

Extensions to PPC. Regarding legacy PPC systems, some re-engineering needs were identified and characterized in order to facilitate the integration of these applications in a VE environment, namely at the level of control of the services offered by the system and its compliance with EDIFACT and STEP information. Additional innovative features developed in PRODNET are the treatment of incomplete and imprecise orders and the management of quality-related information considering distributed business processes practices.

The Sociological-Organizational aspects. Finally it is worth mentioning that the technical developments in PRODNET II were followed by a parallel analysis of the social and organizational impacts and requirements of the implantation of the VE paradigm in SMEs. As a consequence, special attention was devoted to the flexibility and configurability requirements, that became a major design issue, and to the training and internal re-organization necessary in the enterprise. A set of guidelines for managers, software developers and employees were produced.

MAIN ACHIEVEMENTS IN OTHER PROJECTS

Since it is difficult to summarize the results of the large number of projects on VE, this summary is only based on the contributions to the PRO-VE'99 which represent a good sample of the advanced current research work and tendencies in the field.

Infrastructures

The Esprit VEGA project (Zarli, Poyet, 1999) develops a CORBA-based integration platform for VEs. It adopts a workflow based process management approach, following the WfMC reference model. An interesting feature of the architecture is the distributed workflow service for global monitoring of processes across companies. VEGA is strongly centered on the exchange the STEP data.

The Esprit COWORK project (Alzaga, Martin, 1999) aims at supporting product designs in a network of SMEs. Although making some proposals in terms of infrastructure, its goal is not the design of a general infrastructure but rather the understanding of the design process. The main results of COWORK could therefore be seen as applications that could benefit from an infrastructure as proposed by PRODNET II, NIIIP or VEGA.

The Esprit PerDIS (Sandakly et al., 1999) is another project addressing the support for collaborative engineering in a VE, but more focused on the infrastructure aspects, than the COWORK. Major features are the distributed version of SDAI (STEP Standard Data Access Interface), and the focus on aspects of object storage persistence and access performance.

Finally, the Esprit LogSME project (Hunt et al., 1999) proposes an "application-oriented" approach to supply chain and VE management. The emphasis is on the identification and characterization of the application tools for the various business processes in a food supply chain. The emphasis on general infrastructure is limited. Although based on CORBA and DCOMM technologies, the approaches for integration and information management are yet to be developed.

These four projects do not put much emphasis on the safe communications or on the use of EDI for SME data interchange.

Multi-agent Systems approaches

Another interesting approach for the development of generic infrastructures for VE is based on the Multi-Agent Systems paradigm. One example is the ICAS system (Shen, Norrie, 1999) that proposes a collaborative multi-agent based infrastructure supported on Internet. One interesting aspect of this work is the identification and characterization of several classes of agents (coordinators, yellow pages, collaborative interfaces, knowledge management agents, high level collaboration agents, etc.) and collaboration support mechanisms for organization and coordination of communities of agents. It is an interesting conceptual work still to be validated in practical application scenarios.

Another example of application of MAS in VE is found in the work of (Reis et al., 1999) which proposes a model for MAS coordination in task scheduling for integrated logistics environments.

VE Operation

Some other projects are more focused on the VE operation management than on the infrastructures development. This is the case of Esprit FREE project (Wognum, Faber, 1999) that is focused on the support for the management and improvement of the operation of the VE. The main contributions of this project include the provision of: i) an organizational model, ii) a framework to assess the capabilities of current practices in VE, iii) a method for the performance measurement of the VE activities in operation, and iv) a framework for improving the quality of operation of a VE, and v) the identification of potential problem areas with respect to collaboration in VE.

The Brazilian VIRTEC project (Bremer et al., 1999) represents another class of projects devoted to assist a group of enterprises in forming and operating as VEs. The candidate enterprises are registered in a common directory, the so-called Virtual Industry Cluster. This cluster is an aggregation of companies from diverse industries, with well-defined and focused competencies, that can cooperate in a VE. Another contribution of VIRTEC is the Virtual Enterprise Broker that searches for business opportunities and tries to establish a VE, from the cluster members, that fits the customer requirements.

The ICIV (Tononi, 1999) is a project aiming to design and experiment new business models as induced by the VE paradigm in a group of selected pilot test cases. The project is also analyzing the various forms of structural organization of aggregations of SMEs. Being more focused on the VE management aspects, ICIV does not give much contributions to the infrastructure area.

Another project focused on the management area is the work of (Kaihara, 1999), focused on the optimal supply chain management and with a formal basis.

Partners Search and Selection

The creation of VEs is the focus of attention of another group of projects. In this line, the Telematics TELEflow project (Katzy, 1999) develops a framework for the organizational design of a VE and offers a set of tools and methods to select partners and to re-engineer the business- and logistic processes. A detailed analysis of the actors, roles and the design tasks involved in the VE creation is performed.

The work of (Rocha and Oliveira, 1999) proposes a market architecture approach and a multi-criteria negotiation protocol for the VE formation. The Market Agent, a kind of broker that is created each time a business opportunity is identified, is introduced. Potential member enterprises are also represented as agents. The authors formalize: the negotiation protocol for this multi-agent community, the bid request formulation, bid formulation, and the bids evaluation. A necessary further step is the validation of this model with a practical application scenario.

Another research and development work on partners search and selection for VE is from the United Nations University in Macau (Janowski et al., 1999). The VE is modeled in terms of the services it can offer and receive from its environment. This model is used to automate the partner selection process. The main contribution of this work is the strong theoretical basis and formal representations. It is a work in progress that also needs to be validated in practical cases.

Finally, the UK project INDEMAND (Fan et al., 1999) develops a model of supplier capability for machining suppliers in the aerospace industry that can be used in the early phases of supply relationship and selection.

Telework

Finally, a related area, represented by the Telematics COBIP project (Martins et al., 1999), is related to the application of telework in engineering and enterprise services. COBIP is evaluating the application of workflow tools in management of telework decentralized activities. Various real pilot cases are being used in this validation experiment. A workflow management tool and a graphical workflow editor for distributed business process modeling were developed. A closer cooperation between the areas of telework and VE could bring interesting results.

CONCLUSIONS

As a result of a large number of R&D projects several important results have been achieved, both at conceptual level and technologic infrastructures to support VEs. Some of these research results are becoming products that start to be offered in the market.

However, in spite of some converging approaches, the situation is still too "fragmented" with several projects emphasizing different aspects of the infrastructure. There is not yet a common reference architecture that has been widely accepted as the basis for further developments. Before the subject of the basic supporting infrastructure for VE can be considered stabilized, an effort to synthesize the contributions and experiences of different projects is necessary.

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