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A platform to support production planning and management in a virtual enterprise

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Abstract

The materialization of the paradigm of virtual enterprise, although enabled by recent developments in communication technologies and computer networks, requires the definition of a reference architecture and the design and development of a supporting platform and appropriate protocols and mechanisms. This paper describes the approach being developed by the European Esprit project PRODNET, which aims at designing and developing an open platform to support industrial virtual enterprises with special focus on the needs of small and medium enterprises.

Keywords

Virtual enterprise, supply chain management, production management, federated systems

1 INTRODUCTION

Recent developments on communications and computer networking infrastructures represent enabling factors to support more effective cooperation forms among companies which face the challenge of continuous market scenario changes. The formation of a temporary consortium or alliance of companies that share skills and resources to explore fast-changing market opportunities (NIIIP 96, Walton and Whickers 96), i.e., a Virtual Enterprise (VE), may give small and medium enterprises (SMEs) the opportunity to reach world class level and some degree of independence. The manufacturing process is not carried on by a single enterprise anymore. In a networked organization, every enterprise is just a node that adds some value to the process (a step in the manufacturing / supply chain). Although most classic examples of networked organizations can be found in some particular business domains such as the automotive industry, this tendency is spreading to many other areas including the food and agribusiness industry (Camarinha 97b). A number of projects, worldwide, are nowadays

Computer Applications in Production and Engineering. F. Plonka and G. Olling (Eds.)

addressing different aspects of the virtual enterprises. Some of the most representative ones are the North-American NIIIP and the European VEGA, X.CITTIC, PLENT, LogSME, MARVEL OUS and PRODNET.

This paper describes the current approach and preliminary results being developed by the Esprit project PRODNET, which aims at designing and developing a reference architecture and an open platform to support industrial virtual enterprises with special focus on the needs of small and medium enterprises. PRODNET involves 10 partners from Portugal (CSIN, Miralago, Estec, New University of Lisbon, Uninova), Netherlands (University of Amsterdam), France (Lichen Informatique), UK (CIMIO), and Brazil (Fred Jung and Federal University of Santa Catarina).

2 CLASSES OF VIRTUAL ENTERPRISES

The virtual enterprise research is a growing multidisciplinary area still lacking unified definitions and terminology. A number of "competing" terms, such as extended enterprise, supply chain management, electronic commerce, etc., representing related concepts or partial views, are sometimes mistakenly used as synonymous of virtual enterprise. In fact different forms of virtual enterprises can be found nowadays. As a consequence there is clearly a need to classify different perspectives of the VE paradigm before it can be properly addressed and modeled. In a first attempt in the direction of this classification, a number of characteristics can be identified (Camarinha 97a), among which the duration, topology, and co-ordination are described in this section.

Duration. There are alliances made for a single business opportunity and which are dissolved at the end of such process, and long term alliances that last for an indefinite number of business processes or for a specified time span. Typical examples of single business alliances can be found in large scale engineering systems, such as, for instance, building a bridge. In the case of food industry it is more typical to find long-term alliances.

Topology. Another way of characterizing a VE, with major impact on requirements specification for a supporting infrastructure, is to look for the topology of the network. The most demanding case is the one that shows a variable / dynamic nature, in which enterprises (non strategic partners) can dynamically join or leave the alliance according to the phases of the business process or other market factors. But in many sectors there are supply chains with an almost fixed structure (little variation in terms of suppliers or clients). Another facet related to the 'geometry' is the possibility of an enterprise participating simultaneously in various networks or being committed to a single alliance (exclusivity). It is also important to analyze whether the VE operates in a situation of monopoly or under open market conditions.

Co-ordination. In terms of network co-ordination various models can be found. In some sectors, as typified by the automobile industry, there is a dominant company "surrounded" by a relatively fixed network of suppliers (star-like structure). The dominant company defines "the rules of the game" and imposes its own standards, namely in terms of information exchange. Similar examples can be found in the agribusiness sector. A different organization could be found in some supply chains without a dominant company (democratic alliance) in which all nodes cooperate on an equal basis, keeping their autonomy, but joining their core competencies. Once a successful alliance is formed, companies may realize the mutual benefits of having some common management of resources and skills and they may tend to create a kind of common coordination structure (federation). There are less real life examples of federated structures, but it will not be surprising if the market dynamics forces SMEs to embark in such deeper co-ordination alliances. Both related to topology and coordination is the aspect of visibility scope, i.e., "how far", along the network, can one node "see". In many cases a node only sees its direct neighbors (suppliers, clients). That is the case of most supply chains. In more advanced coordination situations, a node might have some visibility over other (non direct) levels.

3 REQUIRED FUNCTIONALITIES

Let us now have a closer look on the basic functionalities required to support an industrial VE (Camarinha97a, Afsarmanesh97).

3.1 Information related functionalities

The following aspects have to be considered:
-Information flows and types: frequency, amount, actors, which takes the initiative, classes (commercial, technical, quality-related etc.), broadcast or point to point flows, etc.
-Shared information: catalogues update and access rights, market information etc.
Interactive electronic catalogues and multimedia based shopping vehicles are becoming more and more important and are likely to become a fundamental component of a VE infrastructure. As the number of end consumers with access to computer networks increases, besides the members of the network, the access to such catalogues will be granted to an undetermined number of "visitors" / clients (home-initiated electronic transactions), with different rights than the VE members. Another example of shared information can be market data. For instance, in the agribusiness sector it is important to have access to worldwide statistics and forecasts on crops production..
-Electronic Trading Posts. Some experiments are already available in terms of using Internet-based "blackboards" for post product offers / buyers notices. More recently some more "active" marketing mechanisms ("push technology"), that take the initiative to forward the information to potential clients, are being experimented. On the other hand, the electronic links also create an opportunity for a much more responsive channel for end user registration and feedback, service and post-sale support than the traditional mail and phone systems.
-Security Some of the most obvious problems requiring a solution are: Access rights and firewalls, privacy and encryption, authentication, validation and auditability.
-Other information related services: browsers, monitoring orders etc.
Fax or other non-electronic media lead to a non-effective monitoring of the orders' status. Delays in orders processing, temporary incapacity of a supplier, changes in not completed orders, the need to re-adjust delivery times, etc., are some factors that point to the need for a more flexible and reliable interchange of information. The implementation of a truly Just-In-Time philosophy requires an infrastructure that supports stronger clients - suppliers interactions.
-Formats and protocols. The extensive use of EDI standards, instead of fax, is becoming a reality for the interchange of commercial documents, like orders. A major difficulty comes, however, from the existence of various versions of an EDI standard. The adoption of STEP for the exchange of electronic product model data throughout the product life-cycle is essential for flow

of technical data between nodes. For other types of information a standardization effort is necessary. Inter-operability between the various standards employed is also a requirement.

3.2 Materials related functionalities

A second class of functional requirements is related to materials flows. It is important not to confuse the flow of information across the network with the flow of products and services through the supply chain, although the two aspects might be inter-related. Some required functionalities include:

-Logistics Transportation, inventory and warehousing planning This includes route planning, vehicles / crew assignment, distribution sequencing, etc., i.e. all activities which provoke materials flow between a point of origin and a point of consumption (Pfohl 96), including the subsets supply logistics, production logistics, distribution logistics and waste logistics.

-Materials flow management Identification, representation and monitoring (according to orders flow and status) of all materials flows within the network.

-Forecasting The use of electronic links to transmit information from points of sale to production units and suppliers, combined with historic data, will allow the implementation of forecasting functions.

-Specific information flows related to product (bar coding, Point of Sale - POS information) In particular it is important to understand and coordinate the interactions between materials flows and information flows.

3.3 Advanced functionalities and requirements

Once an effective electronic interlinking infrastructure is established, it is natural to expect a growth in the number and level of associated services. As the process of alliances (federation) formation among enterprises is a very competition-sensitive one, a step by step creation approach and trust building is the most adequate one. Building confidence and reliability requires experience of co-operation and a clear demonstration of the existence of benefits for all parties. Some early experiments and recent proposals suggest a number of future functional improvements in the VE architectures. Let us consider some examples (Camarinha97a):

Co-ordination. A joint coordination of activities and resources for a more global optimization may be an important step towards a federation-style of network coordination. This will include topics such as: Workflow related services; Distributed scheduling; Definition of roles / assignment of responsibilities; and Collaborative engineering (concurrent engineering over the network).

-Creation / Configuration. Functions to help the formation of a VE, including partners search, decision support tools to help the negotiation process and all the dynamics associated to the joining / leaving of enterprises (definition of roles, duties, rights).

-Characterization by "area" of the network (i.e., position in the value chain). The behavioral patterns of sub-networks may vary depending on their position along the value chain or even their geographical location. There are "areas" that are relatively stable and share some crucial information (strategic partners in the network) and other "peripheral zones" that are much more volatile and involving lower levels of interaction.

-<u>Re-organization and training</u>. Tools to support the internal re-organization / business processes (BP) re-engineering and training of people.
-<u>Configuration tools</u>. Configurability is a must for any supporting platform as we may face many different organizational structures and not a single VE profile.

Also, as some levels of trust, based on personal relationships, may dynamically change (based on reputation), configuration tools must support this dynamism. Figure 1 tries to organize the identified functionalities by levels. At the bottom level there are the most basic ones.

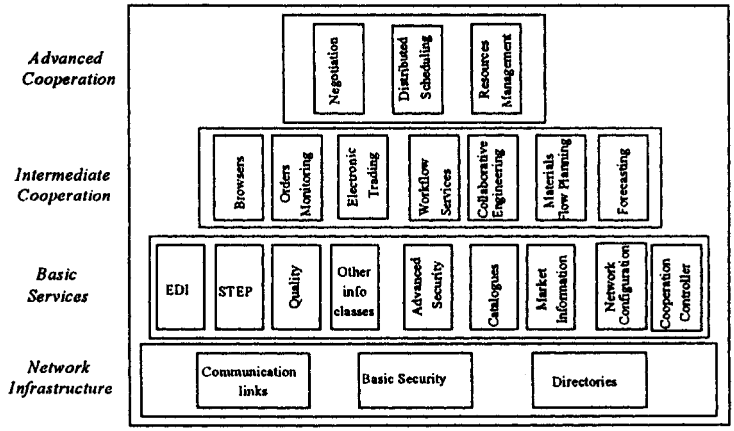

Figure 1 - Some of the basic and advanced VE supporting functionalities

4 PRODNET'S APPROACH

4.1 General aspects

As a basic 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 of other enterprises and uses distinct information management and control strategies that serves its purposes best. The situation is thus one of great heterogeneity and requiring adaptation of existing production planning and control systems (PPC) to electronic linking. However, for these enterprises to cooperate, on one hand they need to share and exchange a part of their information with the others, and on the other hand every company would like to preserve its local autonomy. Furthermore, distinct enterprises have distinct and often contradictory views and semantics associated with the information they store.

To support this environment the PRODNET infrastructure will include two main modules for each node (enterprise) in the network: Internal Module and Cooperation Layer (Fig. 2). The Internal Module represents the autonomous unit of a particular company. It includes the complete structure of the company's information (databases, information systems, etc.) and all the internal decision making processes / enterprise activities (internal PPC and engineering systems). The Cooperation Layer (Fig. 3) contains the functionalities for the inter-connection between the company and the whole net. It represents the communication and coordination role and works as the interlocutor of the company within the net. As a first approach, this module functions as a buffer of information input / output (represented by EDI, STEP, Coordination Information, etc. sub modules) between the enterprise and the network.

Our aim is that "nodes" exchange information, but at the same time, there is a guarantee that existing systems may run independent from the network. Namely, although there will be joint cooperative information exchange within the network, each node can keep its privacy and independence.

One of the necessary components is a kind of Cooperation Controller (PCL) that coordinates the interactions with other nodes in the network. Some of the advanced functionalities are strongly dependent on several non-technical factors. For instance, global VE coordination functionalities depend on the level of cooperation and trust achieved or desired by the enterprises. For some other functionalities there are already some tools on the market or solutions are being developed in various projects. That is the case, for instance, of logistics planning, forecasting or collaborative engineering tools. Therefore, and taking into account the available resources, the PRODNET consortium is not addressing all these topics. Instead, a subset of functionalities are being developed, including:

- Exchange of commercial data (EDIFACT).
- Exchange of technical product data (STEP).
- Orders status monitoring.
- Quality related information exchange.
- Common information system supporting, not only administrative information about the VE, but also all the information a node (enterprise) decides to make available to the network.
- Coordination module that handles all cooperation related events (execution of a local work flow).
- Configurator, allowing the definition and parametrization of the VE and the behavior of the particular node.
- Extended PPC system, adapted to interact with a VE environment and including the management of incompletely and imprecisely specified orders (along their life cycle).

Additionally, the usefulness and implementation feasibility of some more experimental modules on advanced coordination functionalities will be investigated:

- DRP - Distributed Resources Planning.
- Negotiation support system to facilitate partners search and the contractual processes during the formation of a VE.
- Management of a contracts data base.
- Electronic catalogue and its supporting services.

In terms of software organization (Figures 2e,3), some of the mentioned functionalities (EDI, STEP, Cooperation Information, network directories, etc.) deal with basic cooperation services and will be included in the PRODNET Cooperation Layer. Other functionalities, like orders management, are intrinsically associated to the PPC system and will be included in the Internal Module. Finally, the more advanced coordination functionalities will be considered as separate modules, out of the Cooperation Layer, but in strong interaction with it. It shall be noticed that not all enterprises will be interested in all functionalities. Moreover, the various functionalities can be enabled or disabled according to a set of configuration parameters.

4.2 PRODNET Cooperation Layer

As mentioned before, the PRODNET Cooperation Layer (PCL) contains the basic functionalities for the inter-connection between the company and the whole net. It represents the communication role and works as the interlocutor of the company within the net.

The main components of this module are: EDI component, STEP component, Distributed Information Management System (DIMS), Communications component, Authentication and safety modules, External Messages class identifier, Configuration component (CONFIG), Local coordination component, and Human Interface (HI).

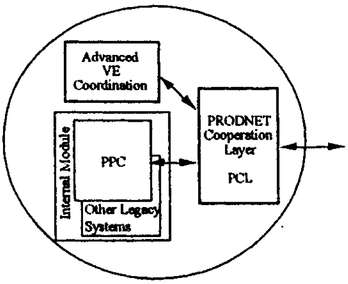

Figure 2 General structure of a PRODNET node

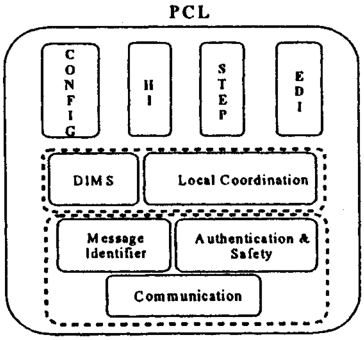

Figure 3 - Main components of PCL

EDI Component. This module is responsible for receiving and formatting orders-related messages in EDIFACT format. Among its functionalities, it will check / parse EDIFACT syntax (for various versions of the standard), check for completeness of messages contents, and generate appropriate formats for sending out EDI messages. It will also detect and extract EDI messages embedding information represented in other formats, such as a STEP specifications associated to an order.

STEP Component. The STEP module's function is to handle the technical product data used within PRODNET. Ideally all product data should be exchanged in STEP format. The STEP services provided to PRODNET will allow for the transmission and reception of STEP files that have been clear text encoded according to a defined schema; as described in Part 21 of the STEP standard. It should also be possible to query that STEP data held within PRODNET by the usage of the Standard Data Access Interface, SDAI, defined as part 22 of ISO 10303.

DIMS - Distributed Information Management System. The Distributed Information Management Subsystem in the PRODNET Cooperation Layer is responsible to model and manage all cooperation support information (Afsarmanesh97), such as:

-*Node Self Information*: information which is controlled and managed by the node itself, e.g. enterprise profile, information which the node wants to make available to the network, local information such as part of a workflow plan, etc.. Any part of this information can only be accessed by authorized users. The Self Information also contains a part of the local information at PPC, that PPC decides to move into the PCL partly for being used within the local PCL and partly for sharing with other nodes.

-*Node Acquaintance Information*: information that needs to be accessible from other enterprises for this node's internal purposes. For example, general profile of other enterprises which can become potential partners in a VE, or information which can be specifically acquired from a close sister enterprise.

-*Virtual Enterprise Information*: this category refers to all the information which is associated with a VE, such as VE configuration information, control and status information for the VE coordinator, information to support the cooperation between the enterprises in a VE, etc..

The implementation of DIMS follows the federated database paradigm.

Communications. This module is responsible for handling all communications with the other nodes in the network. It includes functionalities such as: Selection of communications protocol and channels; Basic communications management; Privacy mechanisms (cryptography); and Tight interactions (direct channels) between nodes.

Authentication and safety. This module is responsible for the implementation of safety and authentication mechanisms, at the VE level. It has to check access rights, handle keys management, etc.

External Messages class identifier. As different classes of messages, coming from the network, can arrive at the PCL, this module will try to identify them in order to facilitate its internal assignment. Examples of such classes are: EDI messages, STEP messages, general PRODNET messages, DIMS queries, etc.

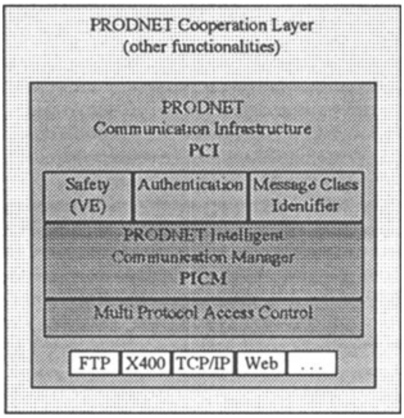

Figure 4 Communications infrastructure

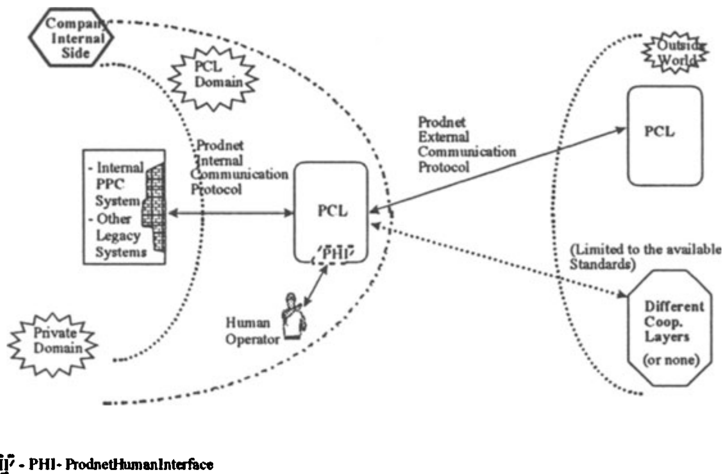

Figure 5 Interactions with the PCL

It shall also be noted (Fig. 5) that PCL has to interact not only with nodes having a similar PCL but also with foreign cooperation layers. At the moment, for foreign cooperation layers, only standardized information messages (EDIFACT and STEP) are considered.

Configuration Component. The PRODNET platform is intended to support a large diversity of enterprises and interconnection modes. This means a large heterogeneity in terms of available / installed services and desired management procedures. For instance, some companies may want to use all communication functionalities and standards, whilst others may be interested in using mainly EDI. Some companies may want a strong human-based control of the interactions process, whilst others may prefer a more direct channel to the PPC system. Therefore it is necessary to specify the desired cooperation behavior in an explicit plan (each enterprise has to define its particular activity flow plan) that will be "executed"/controlled by the Local Coordination Module. Additionally, the Configuration Component will allow a manual specification of the structure of the VE and the access rights of all its members.

Local Coordination Module. This component is the "executor"/controller of the activity flow plan defined by the Configuration Component (a kind of workflow engine). In other words, it is responsible for the behavior of the PCL and interacts with all the other modules. It handles all Cooperation Events according to the specified rules for the particular enterprise. These events have an asynchronous nature and are provoked by other nodes of the VE, by the Internal Module of the enterprise or by the Human Interface.

Human Interface. This component assures an interface between the human operator (responsible for the interactions with the VE) and the PCL. As mentioned before, the level of human intervention in this process will depend on the policy of each company and will be specified at the configuration phase (configuration and workflow plan).

4.3 Main PPC functionalities

According to PRODNET the main functionalities required from a PPC system suited for the needs of a SME are: Industrial Logistics Management: i) Orders flow management, Product data management, Sales Forecasts handling, Actual Requirements Planning; ii) Master Production Scheduling; iii) Production Control; iv) Quality Control / Tracking; v) Industrial Costing. The "gray boxes" in Fig. 6 represent extensions or components of the PPC system that need major re-engineering in order to integrate it into a VE environment.

Mappings. This module is responsible for the interface between the PPC system and the PCL, using the PRODNET Internal Communication Protocol. Such kind of interface has to be developed for each legacy system the company wants to connect to PCL.

Orders management. Orders management is one of the most important functionalities of the Virtual Enterprise. This component is mainly influenced by EDI connections and the possibility of receiving direct inquiries about orders status from other nodes (clients). An explicit state transition diagram has to be kept for each order, however this information cannot be kept in the PCL DIMS. Therefore, the PPC system must be prepared to answer queries about the orders states coming from PCL. Additionally, technical product specifications may be associated to an order and received also electronically.

On the other hand, it is PRODNET's intention to handle orders that, at a given stage, might be incompletely or imprecisely specified. All the dynamics associated to an order, namely the process of receiving further information to complete it, needs to be defined in a good interaction with the PCL system. Let us consider an example of an order for a car model X, where it is possible to specify particular features (optional characteristics), like the type of engine, the color, etc. An **incomplete order** is one which does not include all required product details. An order could, for instance, simply specify a car model X. If an order like that is received then it is possible to start immediately the production of the chassis, the doors, etc., independently of the missing information about complementary attributes. This process continues until all details about the required product are specified. An **imprecise order** is an order in which the value of some attribute is not missing but it is specified in a vague way. For instance, in the car example, the attribute color, in the initial specification, could say "dark color" or "one of blue, black, green". Only later on this attribute would get a specific (precise) value. Another example of vagueness could be on the quantity. An order could specify a tentative amount of between 100 and 120 units (to be confirmed later). New "orders" (or messages) are supposed to arrive in the future complementing the missing attributes in the "original" order (these orders are not really new orders but additions to the original one). Thus they should be associated to the original one (logically merged).

Besides the exchange of the order itself, using an EDI standard, the order has to be followed up in order to cope with, for example, delays in orders processing, temporary incapacity of a supplier, changes in not completed orders, the need to re-adjust delivery times, and so on. A client node might even want to know details about the manufacturing state of the ordered products in order to prevent any difficulties for itself. This requires an infrastructure that supports a stronger clients - suppliers interaction. One important aid to orders management is the order's state transition diagram (Fig. 7). Such diagram can be used to obtain a "snapshot" of the life cycle of any order circulating inside a company. This diagram could also facilitate the follow up of an order during its execution.

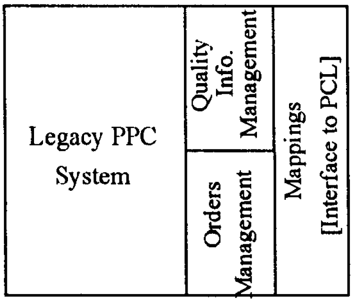

Figure 6 Major changes to a PPC system

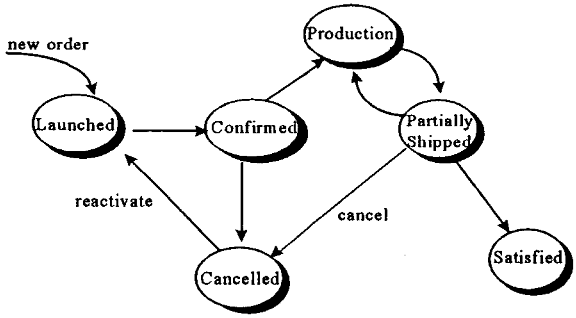

Figure 7 Order's state transition diagram

Quality information management. The extended PPC system will include functionalities to manage the basic information needs for a standard (ISO 9000) quality system (inside the company). At network level, the situation is more ambiguous as there is no standard yet. Nevertheless, new legislation regarding responsibilities for components included in a product will provoke an increasing demand for such information to be exchanged at network level.
In the absence of standard definition of the contents and structure of quality related information to be exchanged between nodes in the VE, the following principles are proposed:
-The report will have a free format [to be agreed between interacting nodes].
-Two levels of reports are foreseen:

i) One related to the value added by the particular enterprise. Examples of information: Who has supplied the raw materials / components; Quality certification information; Identification of production batch, production history; Rejected parts in this production batch; Other production statistics; etc.

ii) Another level with "tracing" information related to components used by the enterprise but supplied by other nodes.

-The access to quality information will be provided on request.
It doesn't make sense to have this information stored on DIMS: it might be a huge amount; it can even be stored on historical backups [not on-line]. Therefore, only a "log" of requests and trace of answers will be stored in DIMS.

PPC imitator. In some industry sectors, some enterprises interact with dozens of very small suppliers (subcontractors) that don't even have a PPC system. It would be however very convenient to integrate these suppliers in the VE supporting infrastructure. This would mean install in such small companies a PC with the PCL module. But in this case, due to the lack of an installed PPC system, it will be necessary to develop a small software module (PPC imitator) that supports manual introduction of the information requests coming from the network via PCL.

4.4 Advanced Co-ordination Functionalities

As mentioned before, the co-ordination aspects of a Virtual Enterprise, although important, still face many open questions, some of them of a non-technological nature. For instance, the legal barriers and the need for re-organizational changes implying retraining of people and new roles assignment (new power structures i) take time to implement and require a very careful approach. On the other hand, the development of advanced inter-network co-ordination mechanisms and safety procedures has to be accompanied by trust building actions, an area whose exact evolutionary shape is hard to anticipate at current stage. These uncertainty factors recommend a step-by-step approach instead of an ambitious general infrastructure development approach as followed by some other projects. Therefore, PRODNET will follow two complementary approaches:

1. A minimal coordination level, mostly based on human decision making, is included in the PCL.
2. A set of experimental components on advanced coordination mechanisms will be investigated:

Decision support system for VE partners search and negotiation. Including: Public announcements (over a network), Use of electronic commerce services, Industrial associations as directories of suppliers, Negotiation, Legal consortia formation.

Management of contracts data base: Contracts with suppliers, Derivation of parameters for the local controller.

Electronic Catalogues: Link to the bidding process, link to WWW / visualisation and browsing.

Distributed Resources Planning (DRP): Abstraction level higher than MRP activity to be done at network-wide level.

5 CONCLUSIONS

This paper presented an attempt to classify virtual enterprises according to the duration, topology and coordination perspectives and to identify the required functionalities for a supporting platform. The structure of the platform being developed by the Esprit project PRODNET was described and a characterization of its main blocks were made. Major open questions, requiring further investigation, are related to the advanced coordination functionalities which depend on the level of integration / federation the companies participating in a virtual enterprise decide to achieve. On the other hand, it is important to note that the concept of VE raises new requirements in terms of methods and contents of work and the skills of the human resources involved. Therefore, the social and re-organizational aspects have to be analyzed together with the technological developments.

ACKNOWLEDGMENTS

This worked was funded in part by the European Commission (PRODNET project). The author also thanks the contributions of the partners of the mentioned project.

REFERENCES

H. Afsarmanesh, L.M. Camarinha-Matos - **Federated Information Management for Cooperative Virtual Organizations**, Proceedings of DEXA'97, Springer-Verlag, Toulouse, Sep 97.

Browne, P. Sackett, H. Wortmann - **Future manufacturing systems - Towards the extended enterprise**. J. Computers in Industry 25 (1995), pp. 235-254.

L.M. Camarinha-Matos, H. Afsarmanesh, C. Garita, C. Lima - **Towards an Architecture for Virtual Enterprises**, Proceedings of the 2nd World Congress on Intelligent Manufacturing Processes & Systems, Budapest, Hungary, June 10-13, 1997.

L.M. Camarinha-Matos, Ricardo Carelli, J. Pellicer, M. Martín - **Towards the virtual enterprise in food industry,** Proceedings of the ISIP'97 OE/IFIP/IEEE Int. Conf. on Integrated and Sustainable Industrial Production, Lisboa, Portugal, 14-16 May 1997, Chapman & Hall, ISBN 0 412 79950 2.

Ingrid Hunt , Alexandra Pereira Klen, Jiangang Zhang- **Cross Border Enterprises: Virtual or Extended !,** Proceedings of the ISIP'97 OE/IFIP/IEEE Int. Conference on Integrated and Sustainable Industrial Production, Lisboa, Portugal, 14-16 May 1997, Chapman&Hall, ISBN 0 412 79950 2.

The NIIIP Reference Architecture, 1996, www. niiip.org

Ricardo Rabelo, L.M. Camarinha-Matos - **Towards Agile Scheduling in Extended Enterprise,** Proceedings of BASYS'96: Balanced Automation Systems II - Implementation Challenges for Anthropocentric Manufacturing, Chapman & Hall, Jun 1996, ISBN 0-412-78890-X.