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A STRATEGIC MANAGEMENT FRAMEWORK FOR COLLABORATIVE PRODUCT DEVELOPMENT

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Abstract
In this article, we introduce a management framework and an IT infrastructure to manage product development processes shared across several enterprises: collaborative, distributed Product Development (PD). This framework serves as a backbone architecture for value added service providers concentrating on information and knowledge brokering and management. The proposed framework has four main layers: processes, models, tools, and physical layers. We will describe and discuss the role of each layer in facilitating collaboration between the distributed development entities. Finally, the framework is illustrated by a case study of an "R&D support network".

Keywords: Collaborative and distributed Product Development, Information Management, Knowledge Management, Information Technology, Structured Framework.

1. Introduction
Global market competition and globalization of operations are forcing manufacturing companies to develop new high quality products at an increased speed and reduced cost. Clark and Fujimoto [1991] observed that intensive, frequent, and bi-directional communication and information sharing are two important strategies for a successful and competitive product development process. However, this strategy proved difficult to implement within a global environment due to several factors discussed in McDonough et al. [1999].

On another front, Electronic-business is also influencing dramatically the ways these companies share and manage their information during Product Development (PD). Rapid advancements of information technologies and computer networking offer new possibilities for a geographically dispersed team to work concurrently on development projects without the need for co-location [Cutkosky et al., 1993].

These above phenomena signal a new era in PD management practice, where companies are outsourcing more and more pieces of their PD process. This leads to a complex and distributed development process requiring companies not only to share and exchange information with suppliers but also knowledge, methods, and tools. The three different levels of distributed collaboration are presented in Table 1.

Table 1. Levels of collaboration in a distributed environment

Level	**Collaboration Type**	**Examples**
1	Information sharing and management	E-mail, data files, PIM
2	Knowledge sharing and management	Expert systems, Internet / Intranet
3	Collaboration architecture	Structure, Roadmaps, common tools

Most advances in IT solutions for PD have focused on information management and data sharing. However, knowledge capturing and management is still a big challenge [Whitney et al., 1999], [Salminen, 1997]. The information and knowledge requirements needed in today's business have dramaticly increased. Tomiyama [1996] has emphasized the importance of knowledge as a core issue in engineering research. The core issue of concurrent engineering is sharing information and knowledge during distributed product development. Beyond well-known communication, organizational and technological problems, which concurrent engineering addresses, we must focus more on knowledge as a source of added value. By intensively using product life cycle knowledge in an integrated manner, we can generate more added value including innovation, longer life, higher reliability and robustness, more flexibility, and cheaper life cycle cost. However, a good and widely accepted, methodology for information and knowledge management in product development does not exist. Consequently, there is an urgent need for a structured framework that facilitates the implementation and execution of collaborative and distributed PD Processes.

Many researchers have worked on this problem, which resulted in the development of several architectural frameworks and models for a distributed, collaborative PD. In what follows we will discuss the most relevant to our proposed framework. Hameri and Nihtila [1997] described a case study where geographically distributed product development teams utilized the World Wide Web (WWW) to share engineering information and data ranging form meeting minutes to 3D models and prototype test results. Their analysis suggested that the WWW can provide the needed functionality and flexibility required for supporting the communication needs of large distributed PD projects. Riitahuhta and Andreasen have suggested for this purpose a paradigm called Dynamic Modularization [1999].

Pahng et al. [1998] proposed an object oriented framework where a large design problem is modeled through the interaction of several distributed modules. Each module represents a specific aspect or concern in the development process and can encapsulate engineering models and software applications. The interaction between the modules is implemented in a “publish” and “subscribe” approach. The major advantage that this framework offered is the ability for the distributed modules (that contain data and tools) to interact and communicate over the network.

The Design Roadmap (DR) framework described by Park and Cutkosky [1999] is a process-oriented model of PD, which enables computer supported collaboration among distributed development teams. The DR framework is built on a directed graph description of the development process, where each node, in the graph, represents an activity, and arcs represent a precedence relationship between the activities. These graphs represent design process templates, which can be reused within their framework.

The framework proposed in this paper differs from the above literature in its focus. While these frameworks, except for the DR framework [Park and Cutkosky, 1999], concentrate on the engineering aspects of product development, our framework is concerned with the management aspect of a distributed PD process. Also, in a way similar to the DR framework [Park and Cutkosky, 1999], we adopt a process oriented view of the PD process in order to facilitate the management of the distributed teams as will be discussed in the next section.

The rest of the article proceeds as follows. In the next, section we present the basic conceptual framework for distributed and collaborative PD processes. In Section 3, we discuss one possible application scenario. Then, we illustrate the proposed framework with a case study in Section 4. Our future research direction in this project is described in Section 5. Finally, we present a summary and our conclusions in Section 6.

2. The Proposed Strategic Management Framework

In this paper we take a process-oriented view of the development process similar to the one described in Park and Cutkosky [1999]. We start this section by defining a process, as used within our framework, and show that this definition is used within the proposed framework. We define a process as a roadmap or recipe for change. Processes do not execute in vacuum. That is, they operate on something to change its state and they require the use of tools to facilitate this change. A schematic of a process is shown in Figure 1. A strategic process is a collaborative process that either requires a model (i.e. information) or a tool form an entity outside its own organizational boundary or is a process that triggers another process outside its own organization.

One of the most important features of the proposed collaborative environment is the definition of a consistent and universal set of strategic processes. They are collaborative blueprints (i.e. templates, recipes, or roadmaps) describing all necessary and required interactions between the distributed entities involved in the PD process.

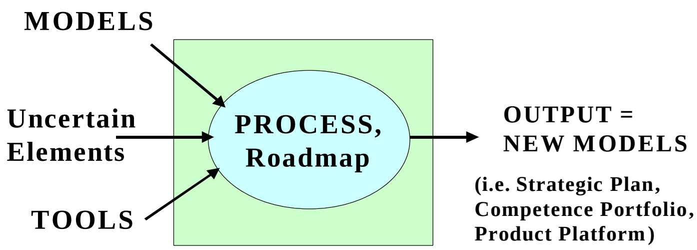

Figure 1. Models and Tools supporting process execution

Systems and tools normally differ from one company to another, but the common IT Infrastructure enables the collaboration by enforcing that the right people are interacting with each others through a common (i.e. standard) process, while eliminating unnecessary interactions. A collaborative blueprint can simply be a binary matrix (Figure 2) highlighting the existence of a relationship (This is also known as a Design Structure Matrix (DSM) as discussed elaborately in Eppinger et al. (1994)). Each "X" in the DSM is linked/mapped to a set of tools in the tools layer and models from the models layer. The execution of a process augments the state of a model and the augmented new model is saved as a new revision of the earlier model.

These blueprints can be attained through several brainstorming sessions that include experts from different organizations involved in the execution of the process. Alternatively these templates can be obtained through a benchmarking effort.

Key Players		A	B	C	D	E	F	G	H	I	J	K
Team A/company 1	A	A	X									
Individual 1/company 2	B	X	B									
Individual 2/company 3	C	X		C			X					
Individual 3/company 2	D			X	D							
Team B/company 4	E		X			E	X		X			
Team C/company 5	F	X				X	F		X	X		
Individual 3/company 6	G			X				G				
Individual 4/company 7	H		X			X	X		H	X		
Team D/company 8	I				X		X		X	I		
Individual 5/company 9	J	X						X		X	J	
Individual 5/company 10	K		X			X					X	K

Figure 2. An example of a Process Blueprint/Template of distributed cooperation and information exchange in PD described with Design Structure Matrix (DSM)

Enterprises should decide on common information logistics and build a set of common strategic processes. This allows for the standardization of cooperative processes and finding out the similarities and differences in their modeling practices and use of tools. Finally, a collaborative IT Infrastructure should be designed and implemented around the established strategic processes to make this cooperation possible through the whole product/service life cycle.

The proposed management framework has a layered architecture [Yassine, 1999], as shown in Figure 3. The layers are: strategic processes layer, models layer, tools layer, and physical layer. Distributed development teams react to the changes in the business environment, which sits on top of the framework as depicted in Figure 3, by interacting through the framework. The business environment plays a critical role in shaping and determining the processes that should be included in the strategic processes layer. The elements in the business environment are usually uncertain and outside the control of any development participant. For example, the strategic process used to formulate a new product platform includes uncertain elements, form the business environment, such as available technologies and competition.

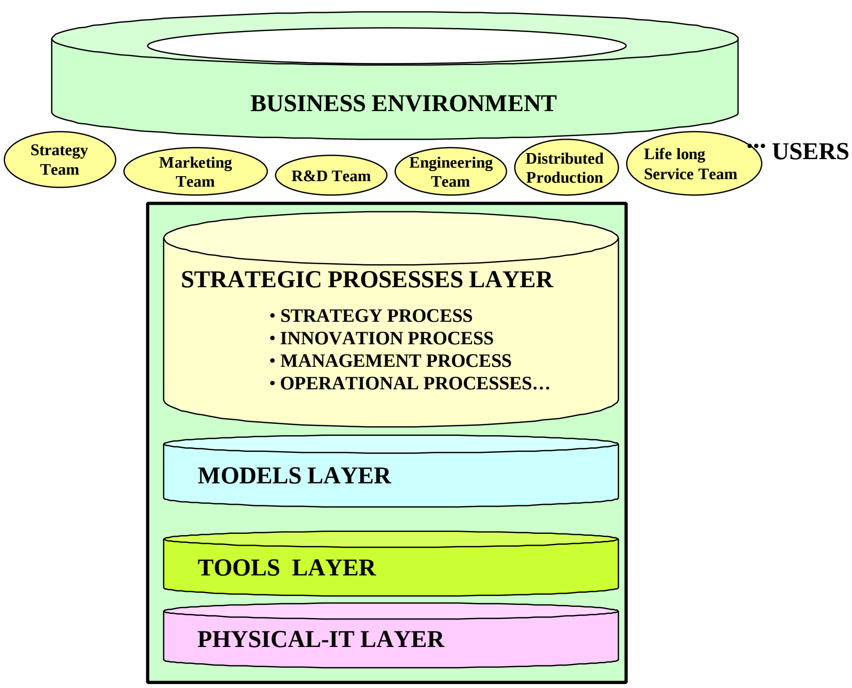

Figure 3. Conceptual Strategic Management Framework to manage distributed product development

The tools, models, and physical layers facilitate and support the execution of collaborative processes that are included in the strategic processes layer. The strategic processes layer provides templates for a set of predefined processes applicable to a specific PD project. Processes can be added or deleted from this layer as necessary and as PD practices evolve within the collaboration with time.

The models layer contains consistent and up-to-date product, process, project, and organizational information. These models can range from simple Excel files to complex 3D solid models. The utilization of standard collaborative processes (defined in the processes layer) and a common tool set (as defined in the tools layer) allow these models to become a common language between development participants. There is no confusion to where a model is used, for what purpose, and with which tool.

The tools layer provides development participants with a consistent set of tools utilized during the executing of collaborative processes. These tools are accessible on demand to the whole development community. Tools might include CAD software (i.e. CATIA), PDM (i.e. metaphase), ERP (i.e. SAP), simulation, supply chain management (i.e. i2), and decision support tools to name a few. Again note that tools that should be included in this layer are dependent of a specific development environment. Finally, the tools layer would eliminate the need for duplication of tools within the development community.

The physical layer facilitates communication, information sharing, tools sharing, and ties up the distributed databases. Security issues are also addressed at this layer. This layer can simply be a computer network with a standard protocol for distributed computing such as CORBA.

3. An Application Scenario

The application scenario presented in this article describes a distributed product development process with value added R&D service providers (i.e. suppliers) as shown in Figure 4. Information technology offers the possibility to use community solutions for the PD partners allowing better groupware environment and use of common models and tools. Approval of semantic issues by all partners is an important part of starting this collaborative partnership.

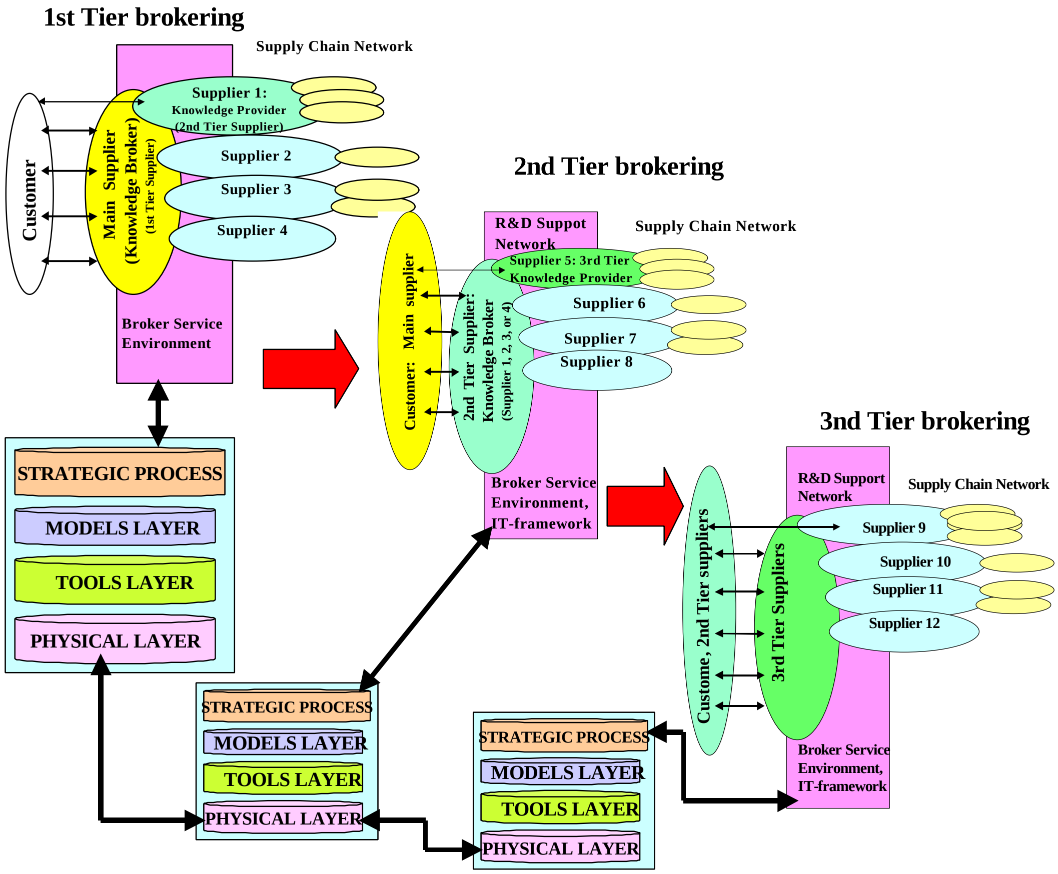

Figure 4. Product Development with supply chain network; broker service environment to support knowledge management

One of the most important decisions is the architecture of the common IT Infrastructure, which enables and manages the desired collaboration between customers, knowledge brokers, and knowledge providers. The main supplier is normally running the broker service for the customer and facilitates the information flows, knowledge management and acquisition/availability of models and tools. Knowledge providers are usually the second and third tier suppliers that provide the required tools, models, or even communication infrastructure.

Within this proposed environment, it is possible to have multi-tiered brokering structure, as shown in Figure 4. That is, a supplier that acts as a knowledge provider, at a certain level of the PD brokering hierarchy, can act also as knowledge broker, at a lower level of the hierarchy. This process cascades down the PD supply chain until all PD participants (i.e. suppliers) are included. This multi-tiered brokering structure facilitates the PD collaboration processes in a consistent and easy to manage process. The multi-tier brokering concept is based on networked competence. Clusters of organizations collaborate with each other by using a common framework to deliver independent elements of value that grow with the number of participating organizations.

4. Case Study: R&D Support Network

The case study is an “R&D support network” that provides information and knowledge management services in a networked environment. The R&D Support Network is an information and knowledge brokering system that has been created in Finland during the national technology program “Improving the Efficiency of Product Development, RAPID” [RAPID, WWW]. It is used in business chain for linking value added service networks to support individual enterprises as described in Figure 4. The R&D Support Network is a source of information and knowledge and is used as broker service environment offering a workspace for the whole supply chain and customer network.

The goal of the R&D Support Network is to support Small and Medium size Enterprises (SMEs) in their product development activities and in the creation of partnerships and support networks. The ultimate goal is to support virtual enterprises working together in the various product development phases, using same methodologies, semantics and process as well as project models and supporting tools. Common semantics, methodologies, models and tools, which are updated by R&D Support Network, are accessible on demand to the whole development community. R& D Support Networks are functioning as application service provider (ASP). R&D Support networks need a conceptual strategic management framework (Figure 3) to act as a backbone for information and operation sharing and management.

Users (as shown also in Figure 5) in the network can be categorized in different groups:

- End users: these are enterprises who are looking for information, knowledge or business opportunities
- Brokers: these are agents that can provoke, collect and manage information and services.
- Information and knowledge providers: these are entities that own the information and knowledge (i.e. processes, models, and/or tools) which becomes available to customers through the broker services. Users of the service may often be mixture of above mentioned groups.

The main process provided by the R&D Support Network is a flexible and modular relationship and partnership management. It has been used in to facilitate the collaboration between various enterprises and academic organizations. Interested companies plug-in (i.e. subscribe) into R&D Support Broker Service (Figure 4) whenever they need to build up a cooperation network/project. Figure 4 shows how supplier 1 uses the R&D Support Network to construct the second tier brokering system, which ties the second tier suppliers into the partnership network. The R&D Support Network allows companies to have access to capabilities (i.e. processes, models, and tools) of many information and knowledge providers.

Independence and trust in this type of community service is very important. The collaborative working process should be based on well-defined internal knowledge and processes based on the companies’ own core competencies. After the competencies have been defined, efforts will be directed towards how to change the culture, processes and technology to support the new way of working.

5. Future Research

The long-range vision, of this research, is that value networks will grow up as dynamic markets in which valued knowledge is traded by value added service providers [Salminen, 1997]. Value added service providers and services would be searched according to agent based methodology. A strategic management framework is an important part of this scenario as shown in Figure 5. We conjecture that the IT Infrastructure for a virtual enterprise has four specific value-added service layers separated based on the strategic management framework: IT Broker service layer, Infrastructure service layer, Information and Communication Technology (ICT) service layer, specialized service layer. System management is based on the proposed conceptual framework and it supports the start up and running of broker services or virtual businesses. It gives the necessary backbone and guidelines for strategy development and management concepts (portfolio management etc.). Networking methodologies and usable tools are restored and downloadable (ASP) from that part of the IT Framework. Broker Service Layer categorizes various kinds of broker services. Infrastructure Service Layer supports partners to use common semantics and metadata base. ICT Service Layer allows partners to do actual distributed work in global network. Specialized Service Layer links specialized tools (e.g. web based project management or documentation tools), which are restored in distributed databases, to be used through ICT service layer by all partners of the whole virtual enterprise.

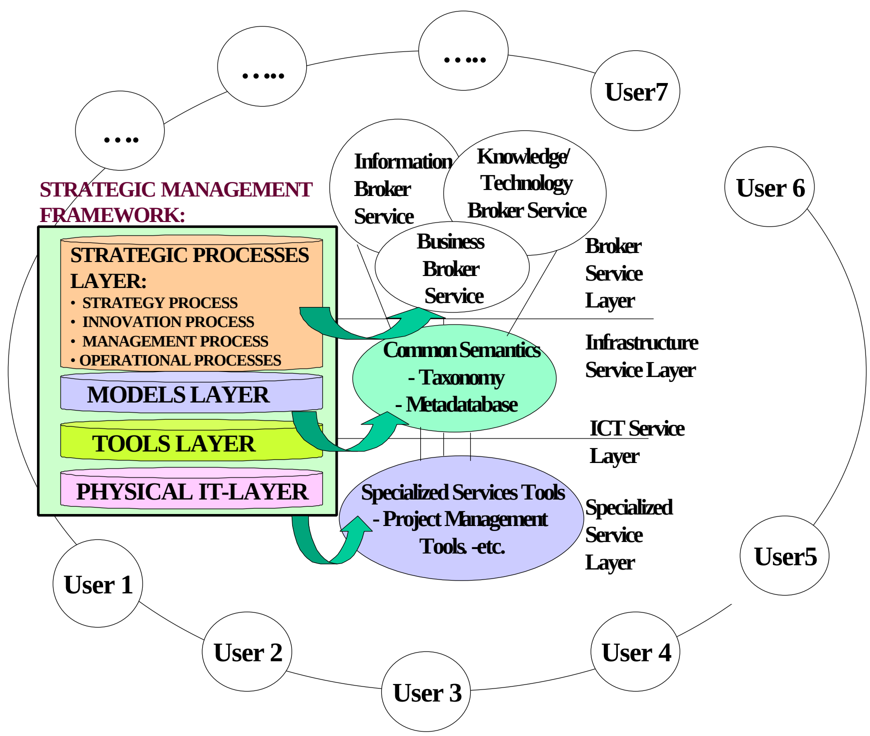

Figure 5. Conceptual future IT Framework for broker services.

6. Summary

There is a great need for value added service networks to support virtual enterprises. Virtual enterprises are enterprises, which concentrate on their core competencies and outsource their non-core businesses forming thus a cooperative network of business alliances. They successfully exploit their intellectual capital and have little physical presence or infrastructure.

Many companies, from different sectors of industry, are changing rapidly towards a networked, virtual business. This kind of business strategy requires newly defined responsibilities, processes, models, and tools. In turn, these are only possible to implement through knowledge systematization, knowledge reuse, and better access to available and existing knowledge. Our case study, the R&D support network, is an effort that tries to give some answers to these challenges by offering the R&D-oriented business network and dynamic project space for clustered enterprises. In this paper, we described a conceptual framework that is needed as a backbone for such collaboration. The framework helps virtual enterprises to formulize their processes and information logistics, to decide on commonly used methodologies/modeling practices and also decide on commonly used tools.

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