A Framework of Implementation of Collaborative Product Service in Virtual Enterprise

X. G. Ming and W. F. Lu,

***Abstract*—To satisfy new market requirements, manufacturing industry has shifted from mass production that takes advantage of the scale of production, to quality management that optimizes the internal enterprise functions, to e-manufacturing era that leverage intellectual capital via collaborative innovation. In the same time, the product itself is becoming the most important asset for sustainable business success. Consequently, the effectiveness, efficiency and innovation for the development of the product across the whole product lifecycle are becoming key business factors for manufacturing enterprise to obtain competitive advantages for survival. To tackle such challenges, a new business model called collaborative product services in virtual enterprise is proposed in this paper. The architecture of this new model is developed based on the framework and the application of web service and process management for collaboration product service in virtual enterprise. Indeed, it is hoped that this architecture will lay the foundation for further research and development of effective product lifecycle management in virtually collaborative enterprise environment.**

***Index Terms*— Product Lifecycle Management(PLM), Product Development, Virtual Enterprise, Web Service.**

I. INTRODUCTION

In order to satisfy new market requirements, manufacturing industry has shifted from mass production that takes advantage of the scale of production, to quality management that optimizes the internal enterprise functions, to e-manufacturing era that leverage intellectual capital via collaborative innovation. In such an e-manufacturing environment, companies need to closely collaborate with customers, manufacturers, and suppliers in a real time manner so as to quickly respond to dynamic customer requirements. In the same time, the product itself is becoming the most important asset for sustainable business success than ever before. Consequently, the effectiveness, efficiency and innovation for the development of the product across the whole product lifecycle are becoming key business factors for manufacturing enterprise to obtain competitive advantages for survival [6] [12].

Supported by the modern Internet technology, collaboration, in the form of both online and off-line, has been recognized as one of the most effective technologies to improve the efficiency and effectiveness of business activities, in both intra-enterprise and inter-enterprise. However, the traditional enterprise application systems [2], such as, Computer Aided Design (CAD), Computer Aided Process Planning (CAPP), Computer Aided Manufacturing (CAM), Product Data Management (PDM), Enterprise Resource Management (ERP), Manufacturing Execution System (MES) are not able to address such needs adequately. This is because they focus on special individual activities in an enterprise and are not developed to support collaborative business requirements specialized in product lifecycle. Many models have been proposed since to meet such requirements in the enterprise level for certain functions of collaboration activities. These includes Product Portfolio Management (PPM), Collaborative Product cusTomization (CPT), Collaborative Product Development (CPD), Collaborative Product Manufacturing (CPM), Collaborative Component Supply (CCS), and also the Extended Product Service (EPS) [8]. Each of these models although addresses certain function of collaboration, they do not integrate all of the above mentioned functions for the consideration of Product Lifecycle Management (PLM). In order to tackle issues of product development in the scope of PLM, a new business model in virtual enterprise is proposed in this paper. This model aim at integrating most of the functions in collaboration mentioned above. The architecture of this new model is developed based on the framework and the application of web service and process management for collaboration product service in virtual enterprise.

The paper is organized in the following sections. The requirement for collaborative product services is first identified. In the Second section, a framework of collaborative product service is developed and the detailed functions of collaborative product services are described based on such a requirement. The web service technology is described and applied to implement such collaborative product services in Section 3. Section 4 proposes the architecture of process management for collaborative product service. Based on the above-developed framework of collaborative product services, web serviced and process managed collaborative product service, the overall architecture of web service enabled collaboration product service in virtual enterprise is developed in the next section.

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It lay the foundation for further research and development of effective product lifecycle management in a virtually collaborative enterprise environment. Finally, the paper ends with the conclusions.

II. Requirements for Collaborative Product Service

A. *Trends of Enterprise Application Systems*

1) Evolution of Manufacturing Enterprise

In past decades, the manufacturing enterprise has evolved from the mass production era, to the quality management era, and now to the e-manufacturing era. The mass production era was characterized by standardized parts and process, economies of scale, producer-centric design, manufacturing, and delivery, vertical orientation, required inventory buffers, locally oriented production, etc. The quality management era dealt with lean manufacturing and shift to horizontal structure and globalization, and focuses on core competency, reliability, durability, and producer led design. To effectively satisfy customer requirements and to improve market value, the manufacturing enterprises have now entered into the e-manufacturing era, which emphasizes on the customer driven design and delivery, flat corporate structures, collaborative virtual networks, mass customization, transparency, speed and agility, global orientation. Along with such evolution, the information content is continuously improved and the responsiveness to consumers is radically enhanced.

2) Evolution of Enterprise Technologies

In corresponding to such evolution in the manufacturing enterprise, the supporting technologies to enable such evolution have evolved and move forward as well. These supporting technologies start from the task automation, to concurrent engineering, and now to virtual enterprise. The task automation technology focuses on the department efficiency by reducing cost, providing functional automation and accurate information, but with no reengineering technical support. The concurrent engineering technology emphasizes on multi-departmental efficiency by reducing cost and in the same time also improving productivity, and is enabled by the technologies, such as process automation and organizational reengineering. In the modern e-manufacturing era, the virtual enterprise technology is promoted with the aim to improve revenue, opportunity, and market share and to reduce cost by leveraging intellectual capital and facilitating collaborative innovation across the networked enterprises. Key techniques, such as inter-enterprise process improvement, inter-organization reengineering, integrated information networks, are developed to support the implementation of virtual enterprise for the e-manufacturing era. Therefore, the virtual enterprise technology becomes one of the most important technologies that support the continuous evolution of today's manufacturing enterprises.

B. *Virtual Enterprise*

1) Introduction to Virtual Enterprise

In the modern digital economy, the competition of companies is no longer between two single companies. It is between two big value chains. Such a value chain is composed of virtually integrated enterprises across the whole vertical and horizontal manufacturing industries by using Internet technology to form a completely networked organization to leverage the core competencies of each member enterprises. Such a networked organization is called Virtual Enterprise (VE) [4] [5] [9] [10]. This Virtual Enterprise normally goes through the following lifecycle processes:

(1) Research of the industry
(2) Application of the virtual enterprise business model
(3) Organization of the collaborative network
(4) Legalization of the collaborative network
(5) Collaborative business network planning
(6) Qualification of participant companies
(7) Business development for the virtual enterprise
(8) Creation of the virtual enterprise
(9) Operation of the virtual enterprise
(10) Dissolution of the virtual enterprise

Nowadays, the Virtual Enterprise has started to form and apply in many business activities, such as the application to Small and Medium Size Enterprise (SME), the collaborative e-Marketplace, and the fortune 1000 multi-divisional applications.

2) Virtual Manufacturing Enterprise Ecosystem

As companies are moving towards providing better and better customer-centric products and services to improve market share and market size with continuously growing revenue, the efficiency and effectiveness of product lifecycle management becomes much more important. Product Lifecycle Management (PLM) is a strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across the extended enterprise from concept to end of life – integrating people, processes, and information [3]. Product Lifecycle Management systems support the management of a portfolio of products, processes and services from initial concept, through design, launch, production and use to final disposal. They coordinate and collaborate products, project and process information throughout new product introduction, production, service and retirement among various players, internal and external to the Original Equipment Manufacturer (OEM). They also support a product-centric business solution that unifies the product lifecycle by enabling the online sharing of product knowledge and incumbent business applications. As such, PLM is supposed to enable manufacturing organizations to obtain the greatest competitive advantage by creating better products in less time, at less cost, and with fewer defects than that of their competitors. In summary, PLM not only provides service for the whole product lifecycle process, but also enables the effective collaboration among networked participants in the product value chain, which differentiates it from the traditional enterprise application systems, such as Enterprise Resource Planning (ERP) and Manufacturing Execution System (MES).

C. *Collaboration*

Collaboration is one of the most effective technologies in today's competitive business environment, particularly, in the product customization, development, manufacturing, supply and services. In view of the nature of the collaboration itself, it can be classified into five levels, which are communicative, collective, cooperative, coordinated, and concerted:

(1) The nature of the communicative collaboration is that it is dialog and common understanding, and dominated or egalitarian, information sharing and non-task oriented. The process of communicative collaboration is normally informal or semi-informal, conversational, chaotic, unstructured and uncoordinated. The applications of communicative collaboration include email, chat, notes databases, news groups, and computer-mediated communication etc.
(2) The nature of the collective collaboration is that it is individual, separate, and piece-meal tasks. The process of collective collaboration is individualized with start and end, and supports minimal integration. The applications of collective collaboration consist of work processing, spreadsheets, graphics, etc.
(3) The nature of cooperative collaboration is that it is usually group-based, and uncoordinated. Its process is normally ad hoc, separates tasks toward common goal, and supports final integration. The applications of cooperative collaboration are composed of net meeting, application sharing, etc.
(4) The nature of coordinated collaboration is that it is usually precedential and happens in the sequential teamwork. It process is usually chronological, step-by-step, ordered, handoff, workflow-oriented and supports progressive integration. The application of coordinated collaboration includes workflow.
(5) The nature of concerted collaboration is that it is mutual and communal. Its process is usually jointly shared, synchronized, continuously integrative, simultaneous, flexible, repeatable and customizable. The applications of concerted collaboration include group support systems, computer-supported collaborative work, etc.

As the product lifecycle processes are collaborative in nature, the above collaborative technologies could be applied in the processes of product lifecycle management to provide the effective collaboration support for stakeholder, customer, developer, manufacturer, and supplier for superior collaborative services.

D. Processes in Product Lifecycle

The whole product lifecycle consists of a set of processes, which are functions or tasks to create, transform, and deliver products. These processes include product market strategy, product portfolio planning, product platform planning, customer requirements, product specification, conceptual design, detailed design, design analysis, prototyping and testing, process planning, inventory management, sourcing, production, inspection, packing, distribution, operation and service, disposal and recycle [14]. Past efforts to process management were primarily driven by the desire to improve the efficiency of an enterprise and reduce costs. Successful process management should create processes that meet product developer's expectations, but also support developer value proposition, provide competitive differentiation and contribute to the desired product lifecycle.

E. Need for New Business Model

From the above description of the complex processes in product lifecycle, it clearly indicates that to effectively manage processes with all the related information and collaborative tasks in the product lifecycle is not an easy task. Therefore, an effective computing system is imperatively required. Normally, effectively managing the product development lifecycle can reduce time-to-market. Also, properly improving the product delivery lifecycle efficiently can shorten the time-to-volume. In addition, managing the product lifecycle process effectively can help enhance the time-to-profit. All these require the effective and efficient collaboration among all the processes in product lifecycle. However, currently available enterprise application systems are unable to meet such requirements for the effective collaboration in product lifecycle management. Therefore, a new business model called collaborative product services and the corresponding architecture need to be developed for collaboration in product lifecycle management.

III. Framework of Collaborative Product Services

A. Emergence of Collaborative Product Services

Recently, there has been research and development of collaboration in PLM, such as collaborative product development. One of the most well-known projects in this area are the CyberCut project at University of California at Berkeley [1], and the FIPER project funded by National Institute of Standard and Technology (NIST) of USA [11]. However, the CyberCut technology focus only on the product detailed design, process planning and its service activities and could not impact the whole product lifecycle process for effective business results. FIPER technology is trying to develop the federated environment to support the collaborative product environment, rather than to develop the key technologies that enable the collaborative product service itself.

The proposed new model of collaborative product services to meet the above-mentioned requirements is shown in Figure 1. It consists of Product Portfolio Management (PPM), Collaborative Product cusTomization (CPT), Collaborative Product Development (CPD), Collaborative Product Manufacturing (CPM), Collaborative Component Supply (CCS), and also the Extended Product Service (EPS). In these collaborative product services, Product Portfolio Management (PPM) covers the processes of product market strategy, product portfolio planning, product platform planning. Collaborative Product cusTomization (CPT) includes the processes of customer requirements, product specification. Collaborative Product Development (CPD) consists of the processes of conceptual design, detailed design, design analysis, prototyping and test. Collaborative Product Manufacturing (CPM) includes the processes of process planning, inventory management, production, inspection and packing. Collaborative Component Supply (CCS) covers the processes of outsourcing, and distribution. Extended Product Service (EPS) covers the processes of operation and service, disposal and recycle.

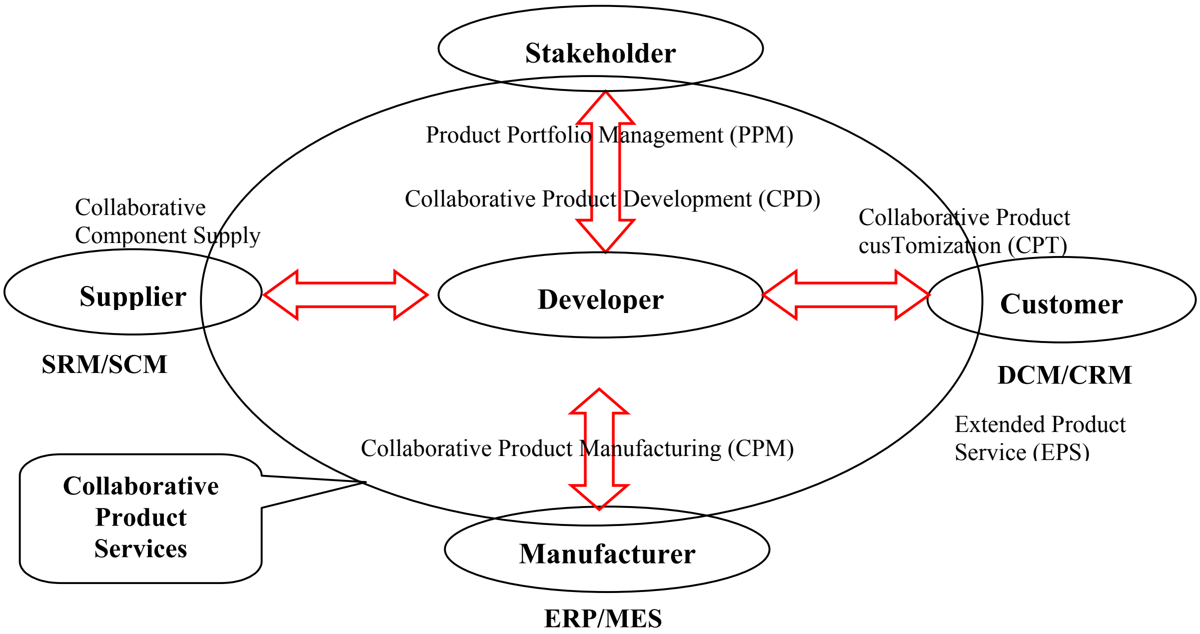

Figure 1: New business models for collaborative product services

Such new technologies will improve the *efficiency and effectiveness* of current product design and development and leverage the capabilities of companies in product design and development via collaborative innovation to improve the competitive advantages.

B. Functions of Collaborative Product Services

Detailed building blocks for constructing the function of collaborative product services are as follows:

(1) Product Portfolio Management (PPM)
- Product market strategy
- Portfolio, program, project planning
- Product family planning
- Product platform planning
- New product development planning
- New product introduction planning

(2) Collaborative Product cusTomization (CPT)
- Requirements management, including retailer management, customer management, and needs analysis
- Customer collaboration
- Customer-driven design

(3) Collaborative Product Development (CPD)
- Product content management, including product configuration management, product structure management, product specification management, design change management
- Product content creation, including visualization, virtual reality, CAD-to-CAD integration, product design tools
- Workflow management, including design process management, rule based process flow, and design process specification and validation
- Collaborative simulation, including Finite Element Analysis (FEA), virtual prototyping, and testing

(4) Collaborative Product Manufacturing (CPM)
- Manufacturing process management
- Manufacturing resource management
- Manufacturing capacity management
- Product quality management
- Manufacturing history management

(5) Collaborative Component Supply (CCS)
- Supplier management
- Sourcing management
- Component supply management
- Direct material outsourcing
- Supply-driven design

(6) Extended Product Service (EDS)
- Tangible extended product service, including extended intelligence, configuration and customization, adaptive user interface, embedded maintenance, etc.
- Intangible extended product service, including extended product specification services, extended product realization services, extended product delivery services, business operational services, product information services, product recycle services.

In order to effectively develop, deploy, and implement the above collaborative product services, the latest information technology such as web services will be used as an effective means in developing the collaborative product service system.

IV. Web Service for Collaborative Product Services

A. Web Service

Web Service provides a distributed computing technology for revealing the business services of applications on the Internet or Intranet using standard XML protocols and formats [7] [13]. The use of standard XML protocols makes Web Services platform language and vendor independent and this provide an effective platform to support the development

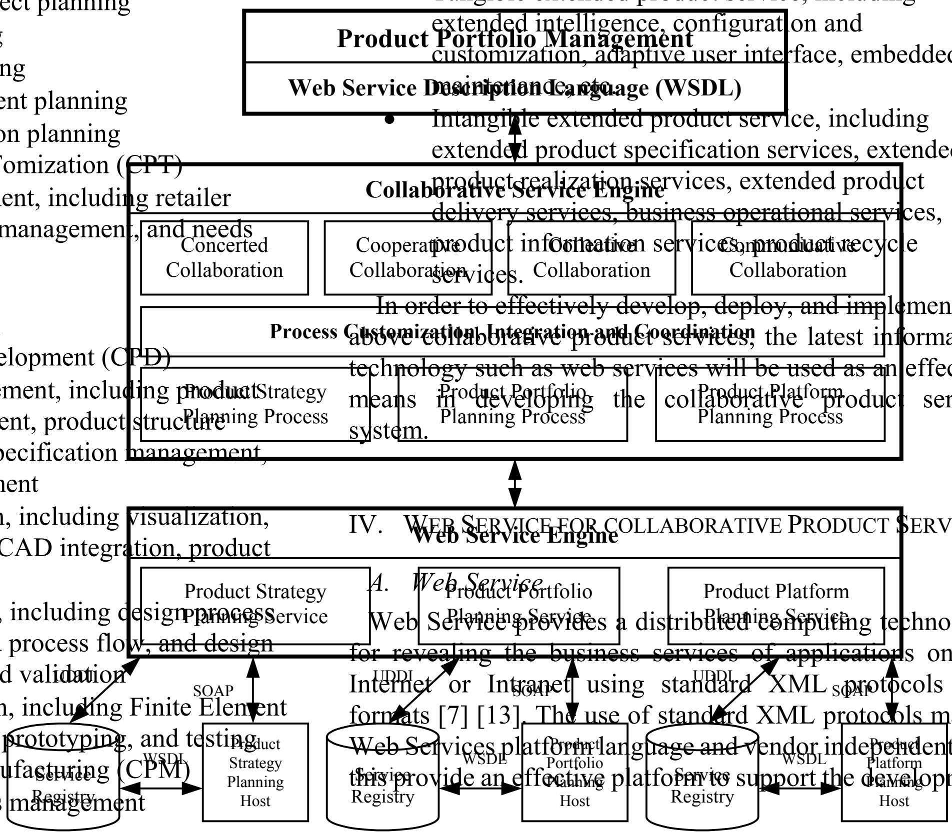

Figure 2: Architecture of web service enabled product portfolio management

of collaborative product services to satisfy mass customer requirements.

Web services are defined as, "loosely coupled, reusable software components that semantically encapsulate discrete functionality and are distributed and programmatically accessible over standard Internet protocols". The technology stack for web services includes:

(1) Web Service Flow Language (WSFL), which is used to define workflows of the web services functions.
(2) Universal Description, Discovery, and Integration (UDDI), which is used to form a central organization for registration, finding and using web services.
(3) Web Service Description Language (WSDL), which is used to describe the format of the web services.
(4) Simple Object Access Protocol (SOAP), which is used to define the protocol for calling web services.
(5) Extensible Markup Language (XML), which is used to define the format for data exchange and description.
(6) Common Internet Protocols, e.g. TCP/IP, HTTP, etc., which provide the basic infrastructure for enabling web service implementation.

By applying the above technology stack for web service, the service-oriented architecture can be established with the following characteristics:

- ✓ Platforms: diverse and unpredictable;
- ✓ Networks: internet ubiquitous and interconnected;
- ✓ Data formats: semantic and shared;
- ✓ Technology focus: interface;
- ✓ Users: suppliers, employees, and customers;
- ✓ Business value: enabling business agility and collaboration.

Therefore, web services technology provides a powerful platform for companies to implement service-oriented business processes, such as collaborative product services. With such a platform, the product lifecycle processes can collaborate with real time feed back from its customers' requirements, and material availability from its suppliers, etc.

From the above discussion, it can be seen that the great potential of web services technologies to be applied in the collaborative product services to quickly response to the dynamically changing customer requirements. However, very few efforts have been reported on the research and development of web service enabled product development. Therefore, there is a compelling need for further research in this area.

B. *Web Serviced Collaborative Product Services*

Considering the nature of collaborative product services and the implementation requirements of web service, a web service enabled framework for collaborative product service is developed as shown in Figure 2 by taking product portfolio management as an example. In such a framework, the highest service level is product portfolio management, which is described by web service description language (WSDL). Such a service is supported by the collaborative service engine, which includes the concerted collaboration, cooperative collaboration, collective collaboration, communicative collaboration, and also the coordinated collaboration in the form of process customization, integration and coordination. The coordinated processes include product strategy planning process, product portfolio planning process, and product platform planning process. This collaborative service engine is supported by the web service engine, which tries to find, load, and implement the real product portfolio management services that are hosted by other service providers. For the other collaborative product services, i.e., CPT, CPD, CPM, CCS and EPS, the general structure of their web service framework are the same as the PPM web service framework.

In such, the business advantages can be obtained as follows:

- Per-process flexibility to adjust to swings in business and regulatory environment on a consistent basis,
- Customized responses to individual requests,
- Decreased development costs,
- Improved user service and satisfaction,
- Decreased operating costs, employing available resources instead of creating new ones,
- Less complex integration – reduced time-to-market of new business services,
- Reduced supplier lock-in,
- Reduced repair and maintenance time and costs.

From the above web service enabled architecture, it clearly indicates that the effective process management, such as customization, integration, and coordination, is one of the key factors for successful implementation of collaborative product services. Therefore, it is necessary to explore a step further in the application of process management in collaborative product services.

V. Process Management for Collaborative Product Services

A. *Business Process Management*

There has been a trend for enterprise application systems to move from supporting single user and single task to supporting multi-users and multi-tasks, where process management takes the key role. In the past, the application systems normally supported for single user and performed one task at one time, such as CAD, CAPP, CAM, etc., and the key enabling technology was the information modeling. In last decade, such application systems have moved to support the integration with each other, such as the emergence of computer-integrated manufacturing (CIM). Such integrated system allows one user to participate in multi-tasks supported by enabling technology, e.g. concurrent engineering. In the same time, some of the system started to provide the groupware-based application with task synchronization, which allows multi-users to synchronously work on one task. Nowadays, as the enterprise application systems become more complex and need to support the scenario of multi-users and multi-tasks, collaboration becomes critical, and subsequently, process management is the key enabling technology in managing these complicated system activities.

According to the Workflow Management Coalition [16], the process is defined as "a set of one or more linked procedures or activities that collectively realize a business objective or policy goal, normally within the context of an organizational structure defining functional roles and relationships". Business Process Management (BPM) is the capability to discover, design, deploy, execute, interact with, operate, optimize and analyze end-to-end processes, and to do it at the level of business design, not technical implementation. BPM is usually top down and model driven.

B. Process Managed Collaborative Product Services

Following the nature of business process management, collaborative product services can also be managed accordingly with the effective support of the business process management technology. As shown in Figure 3, the framework of product lifecycle process management for Collaborative Product Services has been proposed. The framework consists of industry specific product lifecycle process template, product lifecycle process application, abstract process lifecycle management, supporting process technology, supporting standards, and enabling infrastructure. The industry specific product lifecycle process template includes the collaborative product services, such as PPM, CPT, CPD, CPM, CCS, EDS, and product process repository, such as pre-process, process, post-process, function, task, workflow, lifecycle, subscription, notification, role, group, etc. The product lifecycle process application includes the functions of process modeling, process brokering, process managing, and process monitoring. The abstract process lifecycle management consists of the process lifecycle management functions, such as discovery, design, deployment, execution, optimization, and analysis. The supporting process technology is composed of the techniques, such as process automation, manual process, process interaction, process collaboration, process integration, and process configuration. The supporting standards include XML (Extensive Markup Language), BMPL (Business Process Modeling Language), ebXML (e-business XML), ResettaNet, PEDS (Product Exchange Data Standard) / STEP (STandard for Exchange of Product data), etc. The enabling infrastructure includes the latest technologies, e.g., web service, P2P (Peer-to-Peer) computing, grid computing, intelligent agent, collaboration and so on.

Based on this framework, domain-specific product lifecycle processes can be represented by Business Process Modeling Language (BPML). The latest infrastructure technologies, such as web service and P2P computing can be used to implement these product lifecycle processes. The supporting process technologies can facilitate the effective process automation, integration, and customization. The abstract process management functions can be used to support the high-level process management. The product lifecycle process application can provide the domain specific process support by effective product process modeling, brokering, managing and monitoring. The main benefits are as follows:

- Reduced cost of product lifecycle process ownership. Product lifecycle process costs derive from market driven changes in processes, applications and working practices within and outside the enterprise,
- Business agility. Product lifecycle processes become explicit, collaborative, efficient, fluid, adaptable and portable
- Real-time product lifecycle process analysis and optimization. Optimization can be automated, and metrics can be derived as a by-product.

VI. Overall Architecture

Based on the above developed product lifecycle process collaboration, web service enabled product lifecycle process, and product lifecycle process management, an overall architecture of web service enabled collaborative product service in virtual enterprise is developed as shown in Figure 4. The enabled collaborative product service starts with the product lifecycle process requirements captured from market trends, business opportunity, and customer requirements. With such new requirements, virtual enterprise, which is supported by the virtual enterprise lifecycle management, is begun to form. The lifecycle of virtual enterprise goes through the processes of VE business model, collaborative network, business network planning, company quantification, VE development, VE creation, VE operation and VE dissolution. Immediately after VE lifecycle finishes VE quantification, the identified product lifecycle processes, such as PPM, CPT, CPD, CPM, CCS, EDS, from different companies are stored in VE context as a repository. The product lifecycle process modeling is used to represent the details of these identified product lifecycle processes. These modeled product lifecycle processes are then sent to business process management engine for broking, managing and monitoring. The service providers, who implement the corresponding collaborative product services, deliver the detailed function for these processes. The business process management engine then tries to delegate these processes to web service engine. Following this, web service engine looks at the available service at the repository of registered services by using UDDI. The identified services represented by WSDL are captured and the corresponding services are invoked by using SOAP. In such a way, the identified services start to work together under the supervision of business process management engine. The end users, such as stakeholders, customers, developers, manufacturers, suppliers, etc., can now start to collaboratively work together through the collaborative product service portal, which provides the adequate user interface support for product lifecycle users. For each collaborative product service, such as CPD and so on, the required collaborative service for effective product lifecycle management is supported by the all-necessary collaborative technologies, which are communicative, collective, cooperative, coordinate, concerted, and are natively implemented by each service provider or host as shown in Figure 2. In actual fact, such a comprehensive architecture of collaborative product services lays a frontier basis for further research and development in collaborative product services with the contributions as follows:

(1) A unified framework of collaborative product services for new collaborative business models in today's e-manufacturing era,
(2) Framework for the application of web service in collaborative product services to make these services available via Internet,
(3) Business process management for effective lifecycle management and optimization,
(4) Development of collaborative product services in virtual enterprise context to meet the requirements in modern virtually networked enterprise environment.

The collaborative product service system developed based on the above framework will provides profound impacts to manufacturing industries as follows:

Providing effective collaboration for product lifecycle users. Not only does collaborative product service provide access to supply chain and sourcing links that can add value to product design, it also provides the capability to tap the expertise of people never before involved in product design. These includes people who market and sell the product and, most important, customers. With collaborative product service technology, every participator involved with product design, development, manufacture, usage, and disposition can collaborate free of traditional constraints such as geography, organization, scheduling, etc. Product data can be shared and analyzed in various forms: 3D models, schematic diagrams, bill of materials (BOMs), schedules, and forecasts.

Breaking down barriers to innovation. Advanced technology systems used in and related to product design, such as CAD and computer-aided manufacturing (CAM) helped make the individual specific design process more efficient. Design engineers and possibly manufacturing engineers could access these systems, but others who may be able to add value to the design could not involve in product design. By the time these other participants provided their input, changes were either very costly to implement or very difficult to made, resulting in high costs or product design that did not meet customer needs. Collaborative product services, combined with appropriate changes in traditional business processes, can break down these product design and lifecycle barriers between internal stakeholders in product design and all parts of a product's lifecycle. They also effectively extend the power of collaboration to outside entities — suppliers, distributors, customers, analysts, business partners, and others. Collaboration can achieve high design accuracy in real time, avoiding the potential costly mistakes and delays that can cripple the production and delivery process, causing severe damage to a manufacturer's competitive position.

Servicing customer much better. Collaborative product services break new ground in that it extends out to customers after the product is made and delivered. It includes information about "after-market" considerations such as maintenance, service, and warranty. For example, serviceability of a product can be significantly affected by a product's design. Collaborative product services ensure that a manufacturer has the ability to capture, analyze, and react to service data from early designs of a product or similar products. The ability to use after-market information in new product design holds staggering potential, far beyond the obvious cost savings. Data, information and related knowledge on service, repair, and warranty considerations can help manufacturers build and deliver products that have minimum need for service, thereby achieving the ultimate goal of a very satisfied customer.

VII. CONCLUSION AND FUTURE PERSPECTIVES

To satisfy new collaborative business requirements in modern e-manufacturing era, particularly, the increasing needs in collaborative product lifecycle management, a framework of collaborative product services has been proposed. The web service has been employed to implement such a framework. The business process management technology has been applied to effectively manage the lifecycle of collaborative product services. Finally, a complete architecture of a web service enabled collaborative product service in virtual enterprise based on business process management has been proposed. It is hoped that the establishment of such the comprehensive architecture can lay the foundation for further research and development in collaborative product services with following potential benefits :

- ***Reduce time-to-market*** through the sharing of up-to-date information, convenient and effective collaboration, faster and more accurate decision-making, and better control over product development and manufacturing.
- ***Increase revenues***, with the ability to develop innovative products and explore new market opportunities, and reduce the time-to-volume in order to meet rapidly changing customer needs.
- ***Reduce costs*** due to improved management of changes, the ability to track and evaluate projects across product lines, better control over product lifecycle, and improved performance in product lifecycle processes.
- ***Improve product quality*** through integrated quality management that covers product development, production, and maintenance processes, etc.
- ***Increase customer satisfaction*** because of the ability to bring customers into the design chain and to provide effective, innovative, and tailored products that customer wants and then to strengthen customer relationships through maintenance.

The detailed functions of collaborative product services will be prototyped in the future, and hopefully, to be applied in the real application of virtual manufacturing enterprise ecosystems.

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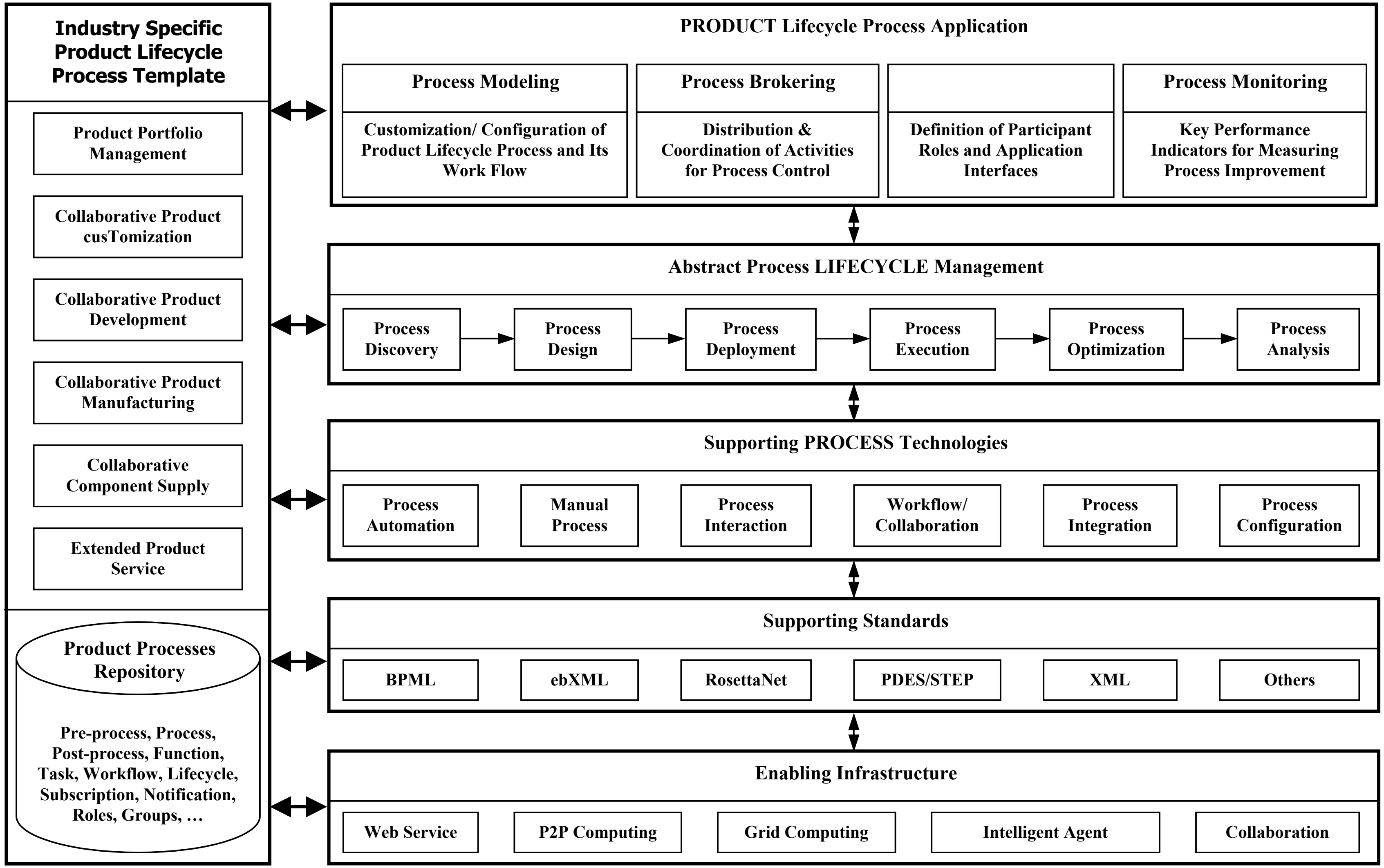
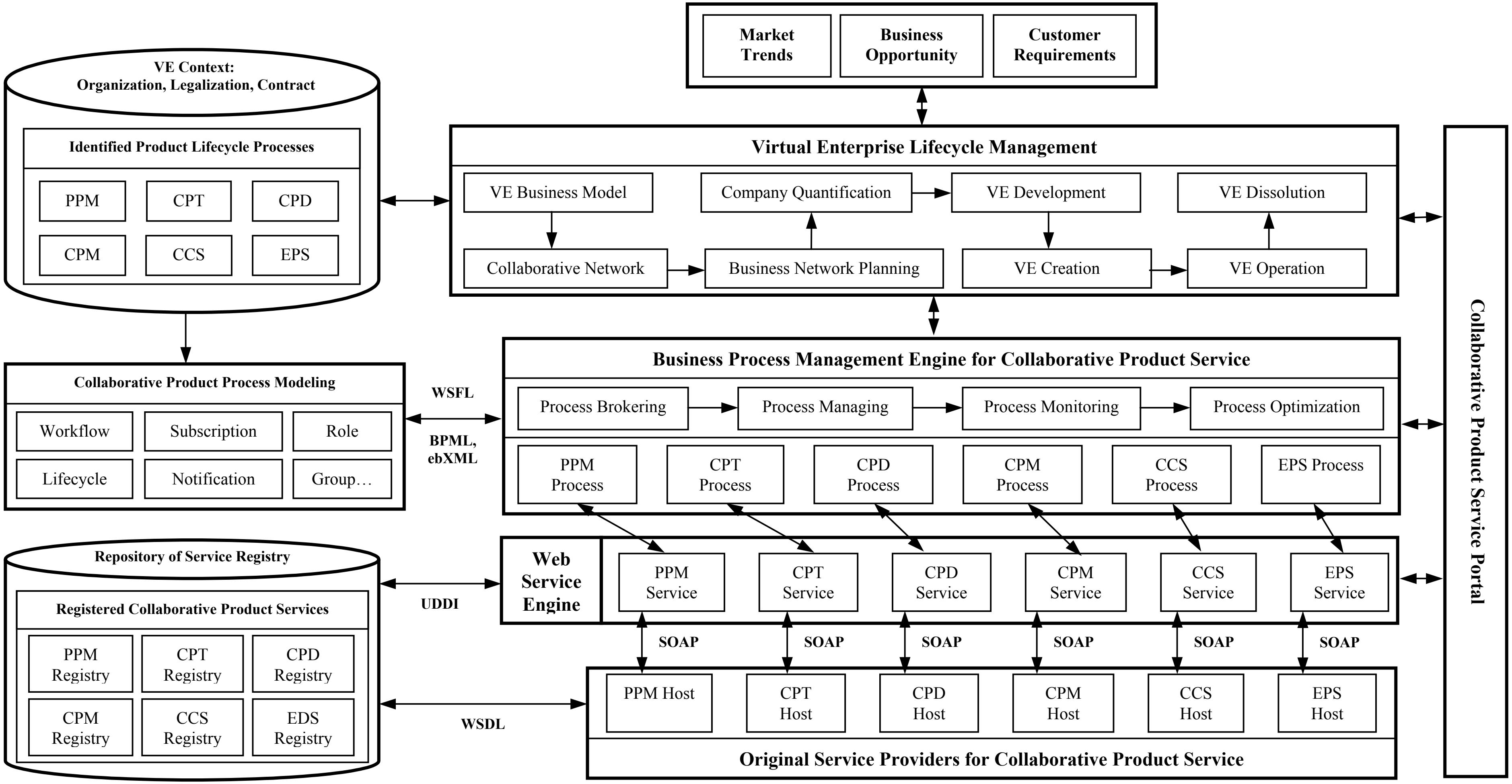


Figure 3: Framework of Process Management for Collaborative Product Services



Legend:

PPM: Product Portfolio Management; CPT: Collaborative Product cusTomization; CPD: Collaborative Product Development; CPM: Collaborative Product Manufacturing; CCS: Collaborative Component Supply; EDS: Extended Product Service; WSFL: Web Service Flow Language; BPML: Business Process Modeling Language; ebXML: e-Business XML; UDDI: Universal Description, Discovery and Integration; WSDL: Web Service Definition Language; SOAP: Simple Object Access Protocol VE: Virtual Enterprise

Figure 4: Architecture of web service enabled collaborative product service in virtual enterprise by business process management