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An Integrated Service-Oriented Development Platform for Realization of e-Business Systems

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I. INTRODUCTION

SOA (Service-Oriented Architecture) is becoming a leading paradigm for the development of information systems and application integration. Web services [1] and Semantic Web [2] are emerging technologies that promote service-oriented architecture and service-oriented e-business systems. With open and standard application interfaces and technologies, Web services implement SOA's features to support loosely coupled applications and their integration. They are expected to transform the Web into a distributed business computation network. SOA bridges the gap between business and information technologies by providing an approach for reengineering business processes with service-oriented approaches and design enterprise information systems with business-centric approaches. A number of IT companies, such as Microsoft, Sun, BEA, HP and IBM have formed working groups to develop Web services' standards and technologies. IBM and HP proposed "business on demand" and "adaptive enterprises", models that are based on the service-oriented paradigm, infrastructure and a number of Web services technologies.

A major obstacle in developing enterprise-level Web services and transactional applications is that the current platforms, such as those that conform to J2EE and .NET, are based on object-oriented component models. Services are developed as objects and common services derived from the object-oriented frameworks. Service-oriented architectures and protocols are implemented based on the above the object model. As a result, the service-oriented functional granularity cannot be realized to meet loosely

coupled and dynamic business processes. These Web services applications have performance limitations in discovery, communication, execution, transaction and security, which restrict SOA's development for large-scale applications. The issue lies in the absence of a service-oriented framework that provides architecture and resources for Web services development, deployment and runtime environments. For example, XML based transportation and process is insufficient without Web services oriented communication and its related resources.

A generic meta-model is central to service-oriented software engineering and framework. By comparing with UML based software engineering for object-oriented applications and AUML based software engineering for agent-oriented applications, service-oriented software engineering is critical to rapid development of Web services applications. The service-oriented software engineering should facilitate service modelling and description, enable service-oriented business planning (top-down) and application development (bottom-up), provide technologies for common semantics and meta-model for service-oriented development methodologies, and specify technologies to enable interoperability between the service-oriented tools and platforms.

Leading IT enterprises are evolving from software vendors to system integration and consultation providers, in order to improve their competency. This strategic migration has created challenges for their capabilities for integration and consultation. The IT enterprises need to be aware of both technical and business requirements of their customers in order to provide services. Based on research on service meta-model, we propose and implement, in this work, a business-centric, multi-model driven and collaborative development platform for service-oriented e-Business systems. The platform has applied a service-oriented framework and model-driven architecture to support service-oriented software engineering. Intelligent Web

services model, BPEL4WS based process model, and business-specific model have been used to support rapid e-Business development and intelligent business process integration.

The platform is intended for business consultants and technical consultants to collaborate in rapid service-oriented e-Business planning and integration, process reengineering and application development. A business consultant models the business by communicating with customers to collect business requirements, define business objects and their relationships, including services and service providers, and plan business processes through a business view and a set of visualized tools. A technical consultant (engineer) improves the business model and employs his/her service-oriented knowledge and IT language to reengineer business processes and implement Web service based applications through a process view and a service view. The collaboration activities are distributed and real-time, which can improve the communication between the participating IT and businesses engineers, and dramatically reduce the design problems and accelerate e-Business development.

The rest of the paper is organized as follows. Section II presents the objectives and related works. Section III describes the architecture and design of the proposed platform. Section VI gives a brief introduction of a case study. Section V concludes the paper.

II. OBJECTIVES AND RELATED WORKS

E-Business systems have become critical for businesses due to the emergence of dynamic market behaviors and rapid changes of customers' requirements. These systems are required to be responsive in real time, flexible in cost structure, and resilient around the world in order to satisfy the needs in the marketplace and the changes in the technology landscape. Enterprises use such systems to streamline their processes, integrate separate business functions, keep processes sufficiently flexible, and reach their customers quickly. The business integration solutions are the key enabler to make on demand business a reality and deliver business values to the customers. Therefore, it is important to have a set of appropriate integration technologies, e.g., SOA/Web services to support the on demand businesses. In this work, we consider, from an implementation point of view, how the on demand business can be implemented efficiently and effectively in order to meet the needs of the customers.

To implement an e-Business system, developers need to capture business requirements and incorporate them into IT systems. Two roles are usually involved in e-Business planning, design and implementation, i.e., business consultants and technical consultants. Business consultants communicate with customers and identify business requirements. Technical consultants have knowledge of information technologies and approaches to support the businesses. The problems with the incorrect and imprecise

communication and understanding among consultants exist due to the fact that they express their views in different languages. A unified and collaborative platform is therefore valuable, especially in implementing service-oriented business systems. SOA is aimed at bridging the gap between business and IT.

Based on the above observations, we have proposed and implemented a multi-model driven collaborative development platform for service-oriented e-Business systems. It supports top-down business planning and bottom-up service-oriented development. The platform supports service-oriented software engineering and application development. The proposed platform is, in itself, driven by three models, i.e., service meta model, process model and business model. In addition to these three models, a service model is designed to support semantic service description and operations, a process model supports the consistency between business process and Business Process Execution Language for Web services (BPEL4WS), and a business model considers services, providers, adapters and their relationships for specified businesses.

In the research of SOA/Web services, academic groups and industries emphasize different aspects of Web service according to their different views on the value chain of Web services. Gartner focused on standard interfaces and loose-coupling of Web services. Microsoft is interested in the integration of Web services, XML, Web and component-oriented technologies. IBM emphasizes service-oriented architecture and composition and Web services' integration capabilities. SUN promotes the employment of Web services' intelligence in order to support customized service, business intelligence, and custom relationship management. In its latest version of SOA specification, W3C enforces Web services' open standards and highlights Web services' capabilities of cross-platform, machine recognizable, and semantic processing. In the previous works [2, 3], we have proposed a semantic service meta model to promote service-oriented software engineering.

Large-scale and rapid applications of Web services need a secure, reliable, and efficient framework for service-oriented application and software engineering. The framework should provide a generic software model and common infrastructure for development and runtime environments. Currently, the existing key frameworks supporting Web services include J2EE and .NET. Based on these two frameworks, the major application vendors, such as SAP, Oracle, Microsoft and IBM, have provided SOA business platforms [4-7]. Many businesses have published Web services and have decided to develop their information systems using SOA. Web services have seen several successful cases in commercial applications, e.g. Amazon and Google, which provide the developers with Web services to customize their own online book stores and search tools. The proposed platform in this paper, however,

is intended to support business process planning, composition and integration.

In the area of business process modelling, there have been a number of object-oriented attempts [8]. Some of them have tried to design a single model to represent the whole business process [9] [10]. It is, however, not an easy task to find a tradeoff between intuitiveness and reliability. Some divided a whole business process model into several sub-models. For instance, FIDO [11] divided a business process model into four sub-models, each corresponding to one aspect of the business. BRADES [12] divided a business process model into three sub-models according to its lifecycle. It is also difficult to determine what business details should be included in a sub-model. Tosi et al [13] tried to build on-demand information systems using KBCS (Knowledge-Based Customization System). Business processes and business objects are standardized and packaged into components with object technologies. All components are deployed independently to one another using the object-oriented modelling methodology. Users can generically and rapidly customize their enterprise applications to fit the business process flow of the enterprise by configuring those required components. Liang [14] presented an object modelling approach to help bridge the gap between business systems and OOIS (Object-Oriented Information System) by building a business system model for an organization and generating an object model from it. The above methods share a common ground in that they are

all based on an object-oriented modelling method. Our platform is service-oriented in process analysis, modelling and implementation. We further provide the ability to transforming from business requirement to IT implementation.

Huang et al. [15] introduced a solution template-based approach for business process integration and management. A solution template is defined as a platform-independent model for business process integration and management solutions where a template is represented through a composition of a set of solution artifacts with an explicit description of the interrelationships among the solution artifacts. The proposed platform takes advantage of this concept along with BPEL4WS to model business processes. Müller et al. [16] described a platform independent model based on the UML2, and mapped it to a platform dependent model based on BPEL4WS. It also demonstrated how the MDA paradigm can be employed at agent-enabled business process architecture. In this work, the process view is similar to Müller's platform specific model (PSM) [17] in that the business processes are described in BPEL4WS. However, the business view of this work is different from Müller's platform independent model (PIM). PIM in UML2 is a high level abstraction of PSM while the platform's business view is not an abstraction of process view. Our proposed method is more concerned with modeling business services and their relationship.

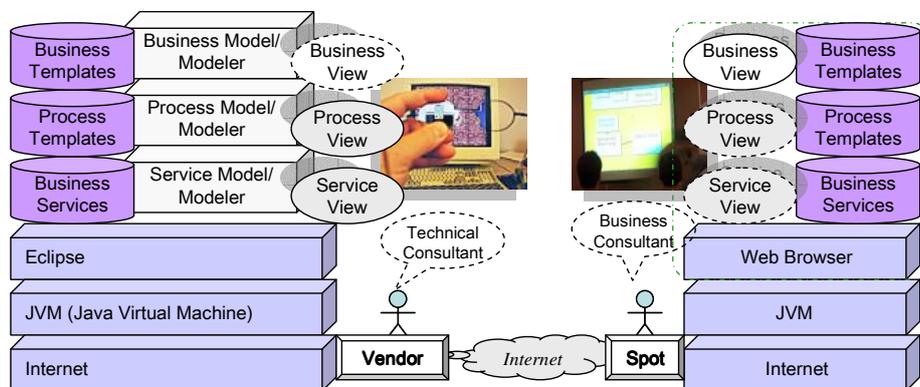


Figure 1. Architecture of the multi-model driven collaborative platform

III. MULTI-MODEL DRIVEN DEVELOPMENT PLATFORM

A. Collaborative and integrated architecture

The architecture of the multi-model driven collaborative platform is shown in Figure 1. The platform supports the service-oriented software engineering and application developments. It employs three views, i.e., business view, process view, and service view to support business and technical consultants' collaborative operations. The

business consultants focus on the use of business view and process view whereas the technical consultants are interested in the use of process view and service view. Consultants can collaborate from distributed sites of, e.g., customers' sites (on the spot) and IT vendors to provide service-oriented e-Business planning and integration, process reengineering and application development. A business consultant models the business by communicating with customers to collect business requirements, define business objects and their relationships, including services

and service providers, and plan business processes through a business view and a set of visualized tools. A technical consultant (engineer) improves the business model and uses his/her service-oriented knowledge and IT language to reengineer business processes, provide necessary information about the internal processes, and implement Web services through the facilities provided by the process view and the service view.

The platform is built on an open source platform, e.g., Eclipse, below which is Java Virtual Machine (JVM). Business consultants use a Web-based user interface. Through Internet the distributed sites are connected. The tools and views are transferred from the platform on the vendor sites to the consultants' Web browsers. In the three views of the platform are three modelers based on the three models. The business modeler is used to capture business requirements, the process modeler is to design detailed process, and a service modeler is to design services. Within the multi-model driven platform, a number of templates are collected from best practices and organized as a set of examples. The business, process and service templates are all individual artifacts, which can be used to compose a business solution for a given business, on demand [18].

B. Three views to design: business, process and service

As shown in Figure 2 and Figure 3, the platform has three views for the consultants to plan and develop e-Business solutions. In order to maintain their consistency, we have developed a set of rules to automatically transform the e-Business subjects among the three views. Consultants interact through the facilities provided by these views to design. To create an e-business solution, a business

consultant starts with the business view and identifies the involved business services, IT services, service providers and their relationships based on the customers' requirements. He/She can choose a business template to assist in modeling, if there is any appropriate business template existing. He/She can transfer the product of the process view to define the business properties of the selected processes (As illustrated by Figure 3).

On the other side, technical consultants with service-oriented implementation knowledge enter into the process view to define execution properties of the selected processes. Based on a selected process, technical consultants can search service directory to check the involved services, if the services are found. Otherwise, the consultant has to transfer the product of service view to create the required services by customizing the existing templates from a library. Otherwise, a new service on the Web services workspace of the service view (As illustrated by Figure 2 on the left) can be created. Another way is to search other sources to find the services that are available, reliable and qualified in the given business. The above operations are repeatable and the consultants can navigate these views to collaborate with each other to complete a business solution design. Based on the identification of businesses, processes and services, description files are generated for the e-Business solutions. There is a compiler, a BPEL4WS compliant engine, provided by the proposed platform to organize, program, compile and deploy these files. A solution can be refined through rounds of definition adaptation and debugging.

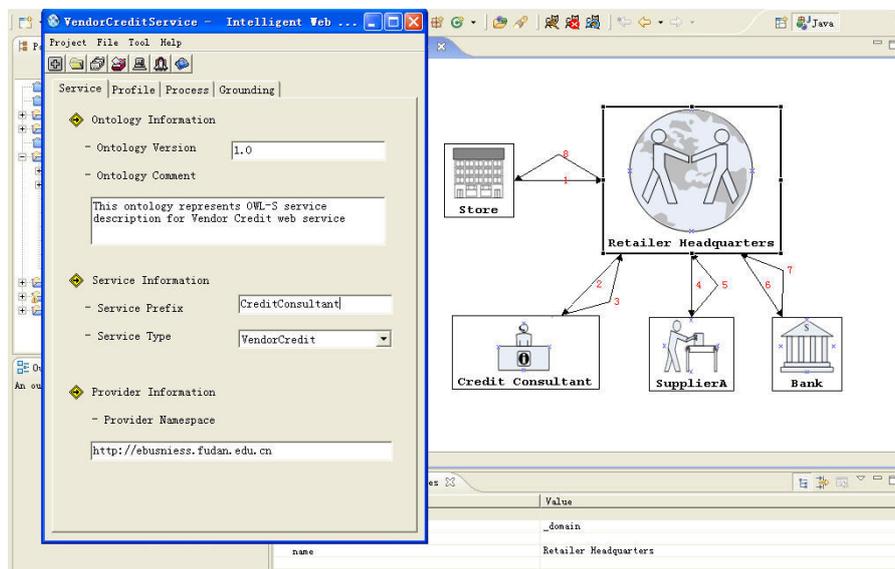


Figure 2. Multi-model driven integrated development platform for e-Businesses

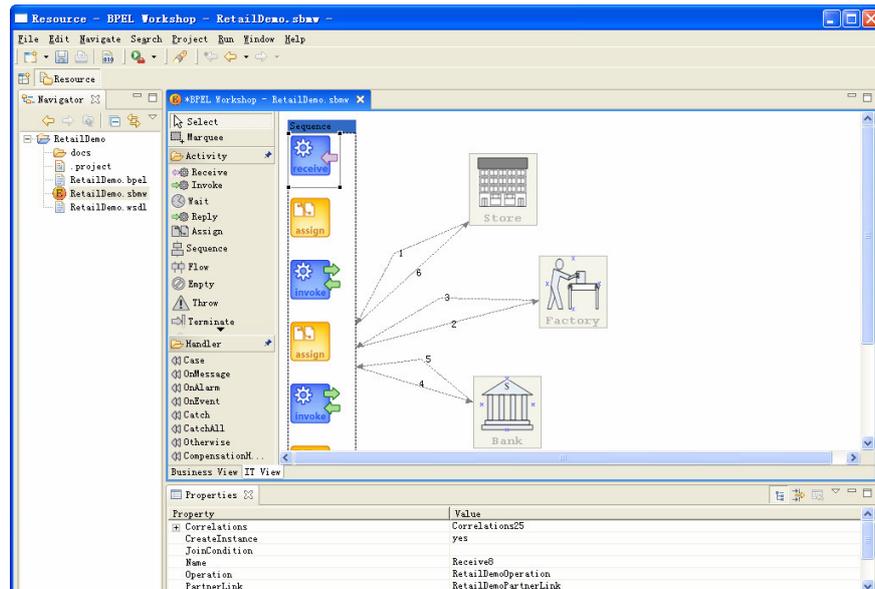


Figure 3. Service model driven development view

The model associated with the solution can be transformed into templates by removing business-specific properties and storing them separately as business, process and services templates. These templates become reusable components. The template-based method is more cost effective than the traditional solution development and it makes business more responsive. Moreover, during the process of using the views and design, a top-down methodology is illustrated through service-oriented business and process planning. A bottom-up methodology is illustrated through the system development based on service composition and process integration.

C. Service-oriented business and process integration

Service-oriented businesses and their processes are implemented through Web services and their interactions. Web services interactions can be distributed across applications and enterprises. An e-Business solution therefore requires the platform to support service interaction by providing a number of common integration services. The business model describes both the pattern and protocol of messages exchanged between the services. Each message may contain one or more types of information required by the services during the interaction. Some of these services can be found at service providers, while others need to be developed by in house.

The platform supports five types of Web services, i.e., business services, platform services and integration services. Integration services are provided to enable template-based integration and collaboration in e-Businesses. They are: (i) coordination and cooperation:

such as adapter services and process-flow-like composition services (ii) ontology and semantic integration (iii) platform services, such as messaging (iv) security services, such as authentication and authorization (v) wrapping services, to name a number of them.

When e-Businesses providers have all service components for e-business systems, they define business templates to compose those services into business processes and applications. Templates describe how services work with each other and how business processes are to be executed. In the platform, business services provide business functions. Common services and platform services provide facilities required by every application. Integration services facilitate interaction between business services by providing agreed interfaces. Coordination services integrate all the services to form process templates and e-business system.

IV. CASE STUDY AND EVALUATION

In a typical retail supply chain, there are consumers, retailers (stores, distribution centers, logistics), transportation providers (carriers), credit authorities, and possibly independent warehouse operators. An inventory tracking department checks shelves and inventory in the retail stores. Once the product stock level is below a specified point, the tracking department requests the distribution center to supply. The distribution center checks the repository in the distribution center. If the stock in the repository is sufficient, the shipment and transportation are arranged. Or, the retailers' distribution center can choose third-party transportation providers and warehouse

operators to deliver the products, if the requested items are insufficient in the repository. In this case, the distribution center requests the logistic department to purchase. The logistics checks the relating suppliers and make inquiries about prices and their credits. The orders will be placed, if the requirements are satisfied. The supplier accepts quotation and replies with prices and terms. The logistics department process purchase orders and arrange shipment, if the prices and terms are acceptable. Once a deal has been decided the headquarter service initiates a request to a trusted bank to make payment to the suppliers. Within this process when the suppliers are determined, the supply chain structure is determined. The business integration solution needs to be developed to support the operations of the above supply chain scenario. In this case, the retailer wants to develop an Inventory Tracking Solution to keep track of the goods movement from its location to the selling floors of the Retailer itself. Figure 2 and Figure 3 are snapshots of implementing a retail supply chain.

To develop such solution, a business process is modeled to describe the actual business operations. The process description provides the details of relating activities and their data flow. The developers through the use of the proposed platform identify the required business and IT services for the solution. The services that can meet the required functions are discovered by searching through service directories. The aforementioned business templates facilitate the search process since it contains pre-identified required services. The associated application, data and B2B adapters are also implemented to form a complete solution. The Inventory Tracking Solution is generated quickly through the use of business templates and intelligent Web services. In this instance, the templates are similar to the Retailer's solutions have already existed in the library. The intelligent Web services identify and mould them to meet the requirements.

The above business has been implemented through the proposed platform. Through this example, the proposed platform and its supporting facilities such as business view, process view and service view has demonstrated that it is functional, feasible, and flexible enough to facilitate collaboration and business-centric and service-oriented solution development.

V. CONCLUSIONS

Enterprises need to be responsive to meet dynamic businesses and requirements. Service-oriented architecture can improve e-Business applications in integration and flexibility. Therefore, service-oriented architecture has been envisioned as an appropriate computational paradigm for e-business applications. This paper proposes a multi-model driven collaborative development platform for building service-oriented e-Business systems. The platform supports service-oriented software engineering and application developments. It employs three views, i.e., business view,

process view, and service view to support business and technical consultants' operations. Consultants can collaborate from distributed sites of, e.g., clients and IT vendors to provide their clients' with rapid system development and demonstration. The proposed platform is service-oriented and driven by three models, i.e., service meta-model, process model and business model. All of these three models are supported by a semantic reasoning engine to facilitate intelligent service discovery, process execution and business-business integration. A simple example has been used to demonstrate its functionality.

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