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Standards-based approaches to B2B workflow integration

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Abstract

E-business automates the overall activities of a company and allows distributed systems to communicate their information. Process automation and information sharing improve a company's productivity and responsiveness, while Business-to-Business (B2B) workflow systems electronically aid the progress of business processes among trading partners, and also help companies to monitor and administrate their process execution. This study analyzes the technologies and standards for B2B workflow integration, and extracts a reference model for B2B workflow integration. Based on the reference model, three approaches to B2B workflow integration will be introduced here. In addition, we have developed a prototype system of one approach and have illustrated an example for B2B workflow integration. The result of our research can help business partners understand the workflow standards and the messaging technologies for B2B workflow integration, and also help them understand how to implement workflow integration systems that are appropriate to their e-business environments.

Keywords: B2B integration; Workflow; Business process management (BPM); Web services

1. Introduction

Many companies have automated their business processes by workflow management systems (WFMSs) and have shared their information in distributed information systems by enterprise application integration (EAI) technologies. Process automation and information sharing help to improve their productivity and increase customer responsiveness. This trend is also emerging in B2B environments. In B2B integration, several companies, such as ones in supply chains or virtual enterprises, try to design their collaboration as business process models and automate them with process enactment engines. The current standards, such as XPDL (XML Process Definition Language), Wf-XML, WSCI (Web Service Choreography Interface), and BPEL (Business Process Execution Language), and the technology, such as web services and message-oriented middlewares, allow the B2B integration to be implemented more easily, extensively and robustly.

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This paper focuses on design and implementation methods for B2B workflow integration. First of all, we have analyzed the research and standards of B2B workflow integration, and then we have presented a B2B Workflow Reference Model, which contains three main interfaces: *Application Interface*, *Human Interface* and *B2B Interface*.

Based on the reference model, we have also introduced three approaches to B2B workflow integration, the *Workflow System Interoperability Approach*, the *Web Service Choreography Approach* and the *Multi-Phase Process Composition Approach*, with the aim of effectively implementing process integration among business partners. The first approach is used to implement system interoperability by extending existing workflow systems in the B2B area. In this approach, reusable private processes of business partners can interact with each other by using the workflow interoperability standard Wf-XML (WfMC, 2001a). The second approach is employed to implement loosely coupled process integration based on web services technology. Application services revealed into web services can be coordinated in a collaborative process by using web service choreography languages such as WSCI and BPEL. The last approach is used for implementing multiple-phase process design including both private and public processes. This approach offers high independency and controllability for each area's processes.

Finally, we have developed ebFMS a prototype system for B2B workflow integration based on the last approach. The system is composed of two process enactment engines: one is a workflow engine for internal workflows as private processes, and the other is a BPM engine for contract processes as public processes. We have illustrated workflow integration with an example of purchase order process through the prototype system.

This paper focused on what should be considered for workflow-based process integration and how we can adopt the recent standard technology, such as web services and business process languages, in implementing process integration. The research we have conducted can help business partners to understand the workflow related standards and the messaging technologies for B2B workflow integration, and to design workflow integration systems that are appropriate to their e-business environments.

2. Background and literature survey

2.1. B2B process integration

Business process management (BPM) has been a significant research issue in the recent decade. The survey of Zhao and Cheng (2005) shows the recent growth of BPM articles very well. In the Business-to-Business (B2B) area, business process integration was considered as one of the most important techniques for e-business application integration (eAI) or B2B integration (B2Bi) (Johannesson & Perjons, 2001; van der Aalst, 2000). Many researchers have been studied various frameworks and languages to realize B2B electronic business, such as B2B commerce, supply chain management and virtual enterprises. In the earlier architecture of electronic commerce, such as eCo (Tenenbaum, Chowdhry, & Hughes, 1997) and EBES/EWOS (1997), process integration was emphasized as a key technical component of the architecture. However, the architecture dealt with only business transactions in little consideration of internal processes. Recently, Baghdadi (2004) presented a layered framework for B2B e-commerce applications (ABBA), which took internal processes into account although he did not show the concreate model for process integration. Meanwhile, business process integration architecture for supply chain management was proposed by fusing workflow with application integration technology (Kobayashi, Tamakia, & Komodab, 2003). The workflow-based architecture aimed at integrating process from suppliers to customers and controlling their tasks, such as sales, manufacturing, logistics and finance. In addition, a process-based framework for virtual enterprises dealt with process modeling, analyzing and managing for virtual enterprises operations management (Gou, Huang, Liu, & Li, 2003). Although those articles suggested different approaches to extended enterprises to B2B area, they illustrated the importance of process integration to integrate enterprise applications, such as customer relationship management and enterprise resource planning systems, and implement the business integration environments, such as supply chain management and virtual enterprises. However, the recent emergence of new technology, such as web services, and several process standards, such as BPEL and ebXML, caused a great change of B2B process integration architecture.

Zhao and Cheng (2005) summarized two recent trends of the BPM domain caused by web services technology. One is the adoption of process-driven application integration by major middleware vendors, like IBM, BEA and Oracle, and the other is the web service-oriented process integration. Web services technology has actually changed a lot of architectures for B2B integration. Peltz (2003) described two aspects of web service composition: first, where orchestration is used to coordinate executable process with internal and external web services in a single company, and second, where choreography is employed to design message sequence implementing business contracts among multiple partners. Two types of service composition can well categorize a variety of works of web service-based process integration.

Business process integration adopted service-oriented architecture (SOA) to serve the companies that would prefer loosely coupled integration in business integration. Many articles proposed process integration architectures by adopting web services. Leymann, Roller, and Schmidt (2002) described hierarchical process structures with service-oriented architecture, which reflected the process design of integrating public and private views. Bussler (2002) also illustrated public and private process management to design B2B integration. In addition, other several researchers also proposed their own specific architecture of process integration, but they rarely cover workflow-based approaches to B2B process integration in consideration of both web services technology and process standards. Workflow technique must play an important role in business process integration because they have already supported effective process enactment and strategic process administration in a lot of enterprises. Moreover, web services technology must be also an important component to implement e-business application integration. In the next section, we will focus on workflow-centered researches of cross-enterprise area in detail.

2.2. Inter-organizational workflow management

Workflow systems provide modeling, executing and administrating of business processes in consideration of organizational models. Moreover, workflow management also supports process analysis and improvement, as well as process automation and administration (Leymann & Roller, 2000). Those kinds of characteristics have made workflow the de facto standard for business process management (Zhao & Cheng, 2005). With the expansion of e-business and internet use, the workflow technique was extended to business-to-business integration, which is called inter- or cross-organizational workflow.

Early researchers of inter-organizational workflow designed the distributed architecture for process and data management (Ceroni & Nof, 2002; Meng, Su, Lam, & Helel, 2002; van der Aalst, 2000) and implemented interoperability systems by defining message format or interface information (Casati & Discenza, 2000; Sayal, Casati, Fayal, & Shan, 2002; Yan & Wang, 2003; Yan, Maamar, & Shen, 2001). In particular, van der Aalst (2000, 2001) presented the methodology to design and verify a global process integrating public and private processes. Johannesson and Perjons (2001) and Kobayashi et al. (2003) extended workflow architecture with agent technology to electronic business and supply chain management. Weigand and van den Heuvel (2002) and Vonk and Grefen (2003) proposed workflow integration methodologies based on contracts between business partners. Those kinds of researches on inter-organizational workflow attempted to adapt the advanced workflow technique to the B2B process integration, and they showed that workflow technique could be effectively used in extended enterprise environments. However, they did not illustrate the practical inter-organizational workflow framework in consideration of recent propagated standards, including web services technology and business process language standards. The framework conformant to standard technology can facilitate seamless process integration with existing workflow systems of the partner companies. In next section, we have introduced some categories of standards related to business process modeling in brief.

2.3. Business process standards

Major solution vendors and e-business consortiums, by contrast, have made various business process definition languages for a more rapid spread of B2B integration. These vendors also presented their solutions conformant to the standards, which in turn provide greater adaptability and feasibility for B2B workflow integration and process-based EAI.

Table 1
Standards for business process modeling (revised from ebPML (2002))

	Control flow	Data flow	Message flow	Transaction	EAI friendly	B2B friendly	User friendly
XPDL	Transition	Process variables	Nested and chained processes	No	No	No	Yes
Wf-XML	Transition	Process variables	Nested and chained processes	No	No	No	Yes
BPML	Block structured	XML	Web services & Global model	Yes	No	No	No
WSCI	Block structured	XML	Web services	Yes	No	No	No
BPEL4	Block structured	XML	Web services	Yes	Yes	Kind of	No
BPSS	Transition	XML	ebXML Message Service	Yes	Yes	Yes	No
PIP	Transition	XML	Web services	Yes	Yes	Yes	Yes

We looked into several business process specifications and their characteristics. The standards, which influence the degree of workflow integration design and its building blocks, can be classified into three categories. First, there are standards related to workflow management, which include various purposes of standards proposed by workflow management coalition (WfMC). Wf-XML is the interoperability specification for heterogeneous workflow engines (WfMC, 2001a), and XPDL is the specification for workflow process definition interchange (WfMC, 2001b). The two standards offer useful functions to be requisite for the cooperation of two or more workflow systems.

Second, several business process definition languages are presented for web service composition and choreography. In the specifications such as WSCI (2002), BPEL (2002) and BPML (2002), process definitions are mostly used to describe external transactions and message exchanges between or among business partners.

Finally, e-business standards, such as ebXML (2001) and RosettaNet (2001), also provide characteristic business process protocols, business process specification schema (BPSS) and Partner Interface Processes (PIP), respectively. This category of standards focuses primarily on the exchange of data and messages rather than on the control-flow among organizations (Verbeek, van der Aalst, & Kumar, 2004). Table 1 shows a brief comparison of business process standards in the three categories.

3. Building blocks for B2B workflow integration

B2B workflow integration implies that business process management extends into the inter-organizational area. B2B integration is not complished by building newly peculiar components for e-business, but rather by coupling their existing systems interactively and link them with external systems of trading partners seamlessly. The internal coupling and external linkage have more significance if the company intends to guarantee its automated trades with the frequent changes of individual business environments. In this section, we expand upon various functions for B2B workflow integration systems from the viewpoint of three interfaces, and also describe a reference model and requirements for workflow integration.

3.1. Three interfaces for workflow integration

In implementing workflow integration systems, various aspects of functions should be considered. We have described the functions in terms of three following interfaces: Application Interface, Human Interface and B2B Interface. The functions of each interface are listed in Table 2.

- *Application Interface*: Tasks in inter-organizational transactions should be supported by various information systems such as the internal operations of an organization. Automated transactions require data of legacy systems such as EDMS (electronic data management system) and DBMS as well as that of e-business applications such as ERP (enterprise resource planning) and SCM (supply chain management). Application interfaces should provide adapters for those various types of legacy systems.

Table 2
Interfaces for workflow integration

Interfaces	Functions
Application interface	Application adapters for automated tasks
	Groupware supports of for participants' activities
	Adapter for external application services
	Analyzer for process relevant audit data
Human interface	Collaboration designer and configuration tool
	Form of input/output in manual activities
	Form of electronic approval or decision making
	Exception handler tool
	Monitoring tool for process transition
	Process controller and administration tool
	Process history analyzer and reengineering tool
B2B interface	Interoperability and business contracts
	Message exchange description and security protocol
	Service description and data dictionary
	Business partner profile
	Message router/middleware
	Message validation checking tool

- *Human Interface*: Human Interface provides tools to help manual interactive activities of participants such as electronic approval or decision-making. In particular, B2B integration requires manual handling tools for potential exception or transaction recovery that may have occurred in automated business collaborations.
- *B2B Interface*: B2B Interface includes all components related to business agreements such as trading procedures, transactions requirements, and message transport protocols. The interoperability standard of WfMC mentions that interoperability contracts should include the issues of data requirements, data constraints, error handling, security consideration, transport protocol specifics, key/id requirements and process synchronization (WfMC, 2001a).

3.2. B2B workflow reference model

A company participating in B2B collaboration reveals some of its activities and allows for interaction with its business partners. B2B workflow integration enables the company to describe and enact business processes that include trade procedures and document exchange formats for the B2B collaboration. We have proposed a reference model for B2B workflow integration as shown in Fig. 1. The purpose of the B2B Workflow Reference Model is to provide the outline for the design and implementation of business process management systems.

Fig. 1 illustrates the reference model for B2B workflow integration, where *Organization A* performs a collaborative process with *Organization B* around workflow systems. The workflow systems of the two companies support the task of end-users (*Human Interface*) with application service (*Application Interface*). Each workflow system can execute public processes that are shared with the business participant's system (*B2B Interface*), while both workflow systems are enacting their own private processes. In the next section, we will describe three approaches to workflow integration according to the ways in which these processes interact with each other.

3.3. Requirements for workflow integration systems

Many researchers have provided various issues to be considered in relation to inter-organizational workflow. Peltz (2003) proposed four process design requirements for web services: asynchronous service invocation, exceptions and transactional integrity, dynamic, flexible and adaptable web service orchestration, and

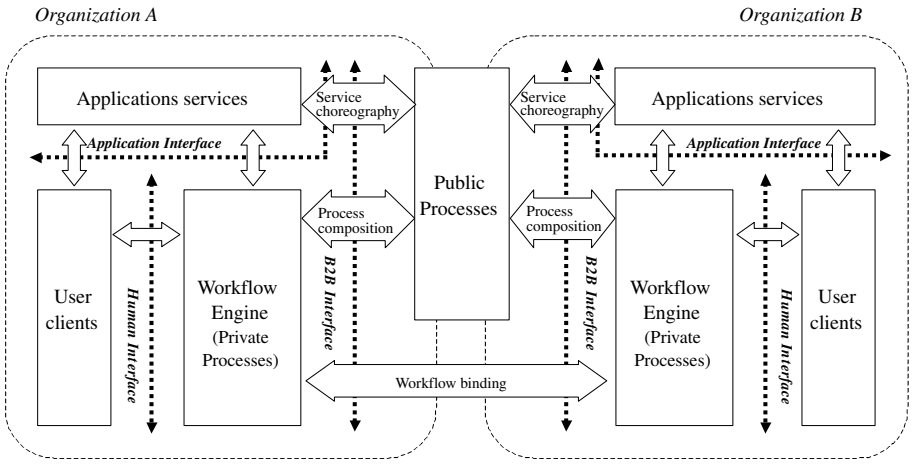

Fig. 1. B2B workflow reference model.

higher-level service composition from existing processes. Wetzel and Klischewski (2004) described the design requirements for inter-organizational process in three dimensions: flexibility support, interoperability and customer orientation. Schmidt (2004), in turn, defined the requirements for the enactment of inter-organizational workflows as enactment autonomy, workflow evolution, knowledge encapsulation, scalability, service autarchy, service extensibility and integration, and asynchronous service evolution.

In this section, we offer more detailed issues to be considered in relation to the design and implementation of the systems for B2B workflow integration environment. These are as follows:

- *Distributed architecture*: Many workflow systems can integrate with each other by using the internet in distributed environments. The architecture needs extensible and scalable design to sustain the system performance, despite additional workflow systems.
- *Flexible message routing*: Message routing should be considered to adjust the change of business partners in similar trade environments in a flexible manner.
- *Transaction management*: The systems can recover the failed transactions in transport-layer and system-level by supporting transaction management.
- *Independency and reuse of workflow*: The systems need to support the independent management and reusability of internal workflow processes. The characteristics will also enable trades with multiple partners.
- *Registration and maintenance of legacy system*: The environment should support the simple registration and participation of the existing legacy systems for various types of business collaboration.
- *Message reliability and security*: The systems should guarantee the message reliability in message-level and application-level, which can accommodate present various security protocols.
- *Role-base control and administration*: This is required to assign and control the appropriate roles for task accomplishment and process administration according to organizational models and roles in collaboration.
- *Adapter support*: The systems should provide the adapters that can invoke or be invoked by systems for e-business and supply chain management.

4. B2B workflow integration approaches

In this section, we introduce three approaches to B2B workflow integration to implement process integration among business partners in an effective manner. These approaches are the *Workflow System Interoperability Approach*, *Web Service Choreography Approach* and *Multi-Phase Process Composition Approach*. The first approach is used to implement interoperation of workflow systems in order to link the private processes directly with each other. The second is used for choreographing Web services in order to extend a public

process to each partner's areas. The last is used to implement multiple-phase process design, including several private processes and a public process, so that this approach offers high independency and controllability for each area's processes.

4.1. Workflow systems interoperability

The first approach to workflow integration is used to implement message exchanges for workflow systems' interoperability. In this approach, workflow systems can communicate with each other by exchanging messages to initiate new processes, to change the state of target processes, or to attain the information of process relevant data. This approach needs no particular means for describing collaborative processes, but rather, message exchanges should be composed for the procedure.

If system architects do not intend to use vendor-specific API or protocols, they can offer higher extensibility and reusability to build interoperability components conformant to the Wf-XML binding of WfMC (2001a). Fig. 2 illustrates a Workflow Systems Interoperability scenario and the message operations and parameters in Wf-XML binding. Wf-XML messages can be used in the case that a workflow engine requests another workflow engine to create a process instance, or to change a state of the instance, or to inquire about the information and execution results of the instance.

This approach may be quite simply implemented by extending the functions of the workflow systems, but it still needs the interoperability contracts, message exchange methods, security issues, and so on. WfMC also provided the following issues related to interoperability contracts: data requirement, data constraints, error handling, transportation protocol specifics, security, key/id requirement and process synchronization (WfMC, 2001a). Weigand and van den Heuvel (2002) suggested inter-organizational workflow integration on the basis of contracts, and proposed a contract definition language. Amin and Keng (2002) presented a type of workflow interoperability architecture among partial processes of trading partners in order to implement inter-organizational workflow in virtual enterprise. Furthermore, Hollingsworth (2002) and Rossi (2002) described the implementation method of Wf-XML binding between workflow engines by using web services technology.

4.2. Web service choreography

The second approach is employed to implement a loosely coupled integration for a collaborative process by using web services. This is a passive approach to call external individual services for a public business process. The process may be also invoked from external web services if the workflow system supports web services calls.

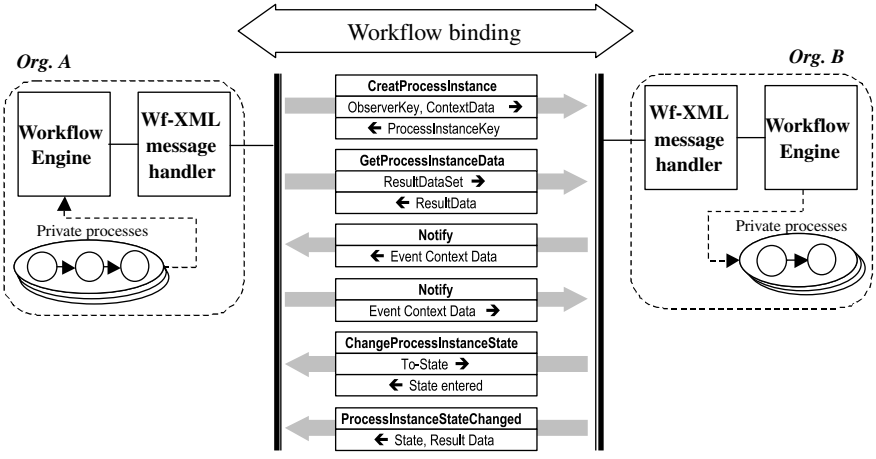

Fig. 2. Workflow systems interoperability with Wf-XML binding.

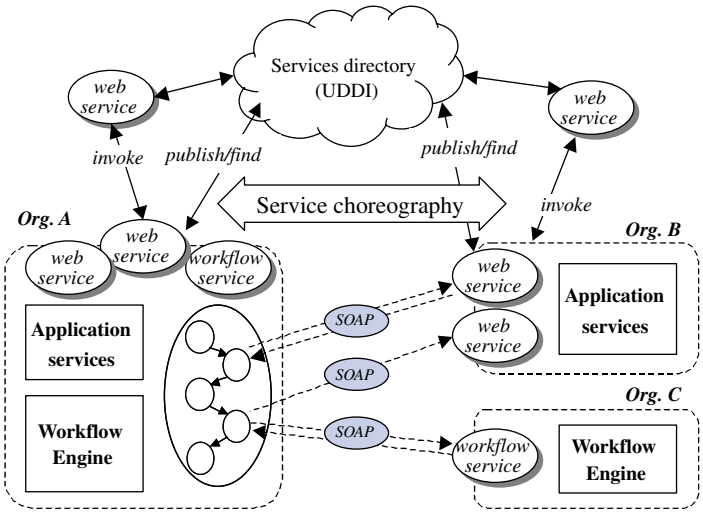

Fig. 3. Web service choreography with UDDI registry.

Using this approach, application services will first be implemented and revealed into web services to be used in collaborative processes; otherwise, existing web services may be discovered from UDDI registry to participate in the collaboration, as shown in Fig. 3. A public process definition will then be composed to invoke those individual services; the process definition can be composed conforming to any business process standard that supports web services invocation.

XPDL (WfMC, 2001b), the workflow process definition standard proposed by WfMC, supports the schema for web service invocation in particular activities of the internal workflow (Fisher, 2002). BPML (2002) also provides the description for the external web services invocation as well as generic application services. Furthermore, WSCI (2002) was presented to choreograph the distributed web services dynamically, and BPEL (2002) is a business process definition specification for web service composition (Lay, 2004). These standards can be used to describe public processes, including external web services. Peltz (2003) and Leymann et al. (2002) described detail methods for web service choreography in the service-oriented architecture (SOA).

4.3. Multi-Phase Process Composition

The last approach is used to implement multiple-phase process design, including both public process and private process. With this approach, internal processes will be enacted independently in the workflow engines, and the processes are coupled with a collaborative public process, which may also be executed independently based on interoperability contracts.

The *Multi-Phase Process Composition Approach* can be implemented in various ways, according to the ways in which a public process and private processes are coupled. Fig. 4 shows a conceptual scenario of the Multi-Phase Process Composition, which illustrates three sub-process models by WfMC (1999). A public process can

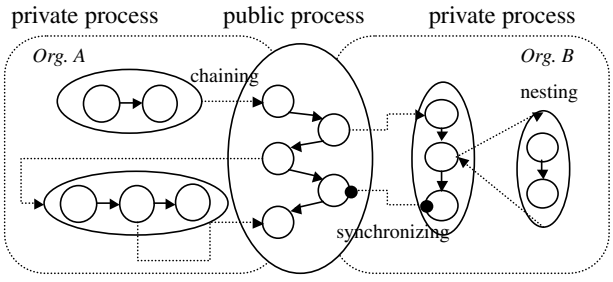

Fig. 4. Conceptual scenario of Multi-Phase Process Composition.

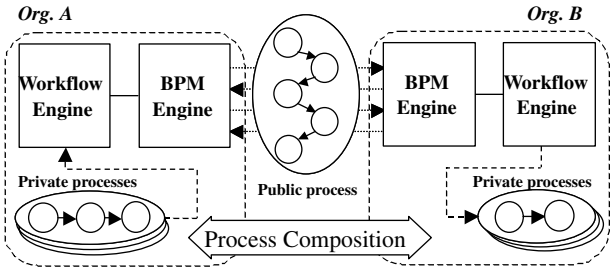

Fig. 5. Multi-Phase Process Composition Approach with BPM standards.

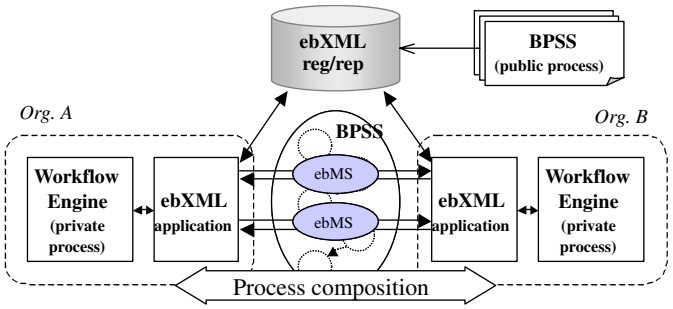

Fig. 6. Multi-Phase Process Composition Approach with ebXML framework.

include private processes as the detailed procedure of its activities in a nested model, and it can invoke a new private process in a chained model. The corresponding activities between two processes can also be synchronized in a synchronized model.

Although the *Multi-Phase Process Composition Approach* is more complicated to implement than the other approaches, it guarantees independent management and maintenance of workflow processes such as reuse or modification, owing to the separation of overall collaborative processes into a public process and private processes.

This approach can adopt process interoperability patterns for more detailed controllability of process composition (Jung, Hur, Kang, & Kim, 2004). Jung identified six primitive interoperability patterns as building blocks to express the complex interaction between two processes. The patterns can be transformed into interoperability operations and implemented into business process choreography by defining interface protocols. Fig. 5 illustrates the system architecture of the workflow integration where public processes and private processes are independently executed and controlled by separate process enactment engines, the workflow engine and the BPM engine.

In addition to the above, business process protocols such as BPSS by ebXML (2001) or PIPs by RosettaNet (2001) can be adopted to define public processes through this approach (Bussler, 2002; Leymann et al., 2002; Weigand & van den Heuvel, 2002). The architecture with ebXML framework will be shown in Fig. 6. Each trading partner will discover the other's business protocol in the repository and will implement service binding based on the message protocol, while the public process will be coupled with its own internal workflows.

5. Implementation of B2B workflow integration

5.1. Workflow integration system: x-ebFMS

We have developed a prototype system for B2B workflow integration by using several standards. The x-ebFMS (XML-based e-Business Flow Management Systems) implemented *Multi-Phase Process*

Composition, the third approach to B2B workflow integration. The system is composed of two subsystems: WFMS and BPMS. The internal workflows as private processes in WFMS were described in XPDL, which was widely adopted as a workflow process definition. In addition, the contract processes as public processes in BPMS were described in BPEL, which enabled B2B integration by using web services invocation. The two subsystems communicate with each other by way of Wf-XML messaging in order to initiate, resume and notify to target processes. The system architecture and integration method of the prototype system can become a reference to implement B2B workflow integration based on standard languages (see Fig. 7).

To manipulate XML-based standard documents for process definition and message exchange, the system adopted Xindice 1.0 of the Apache group as XML storage, and also utilized the Java Architecture for XML binding (JAXB) as a parsing library. By using the XML DB and the Java library, the system queries, interprets, and stores the XML documents conformant to schemas of the standard specifications. Fig. 8 shows the procedure of XML document processing. The engine gives the XPath query to enact processes, and then XML documents of the query results are unmarshaled into java objects. Next, the engine handles the java objects, and then the objects are marshaled to the XML documents again and stored in the XML DB.

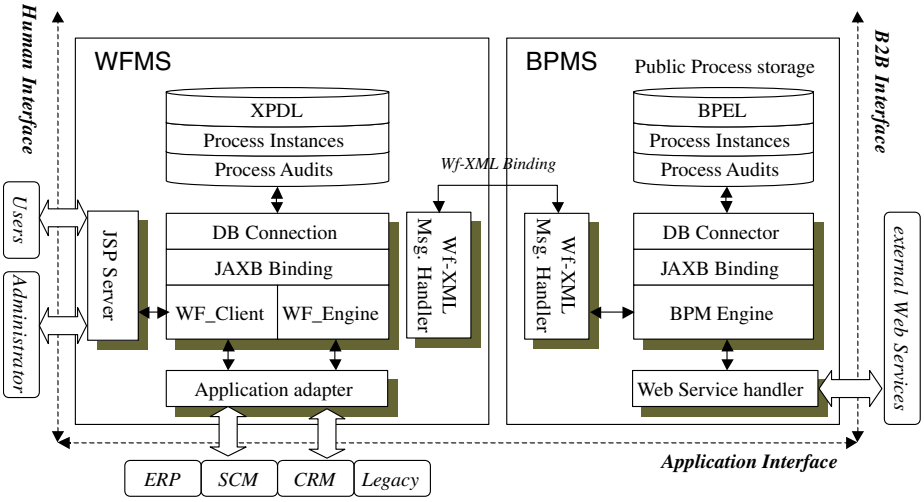

Fig. 7. Architecture of our workflow integration system.

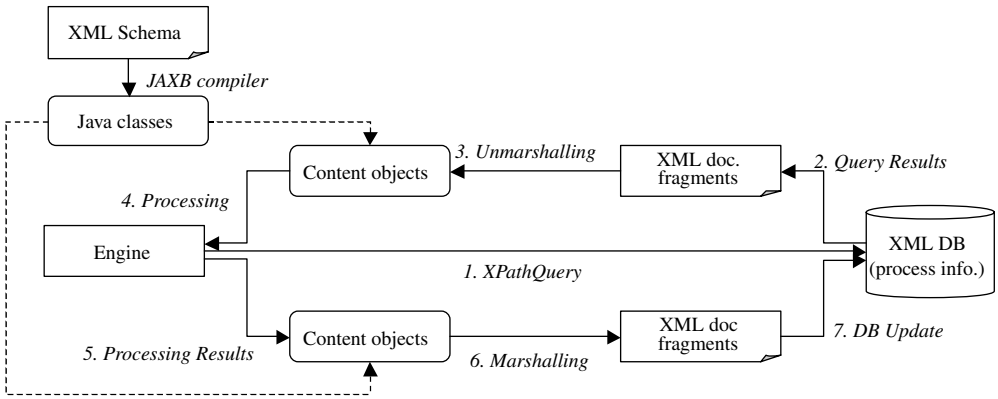

Fig. 8. XML document manipulation with XML DB and Java library.

5.2. Example scenario

We show an example scenario of B2B workflow integration using the *Multi-Phase Process Composition Approach*. Fig. 9 illustrates an example of purchase order process between a customer and a supplier. The *Purchase Process* in the middle of the figure is a public process that describes business logic and message exchanges between two partners. The other four processes are private workflow processes where each partner executes his/her own tasks for purchase order.

As mentioned in the previous section, public processes are enacted by a BPM engine, and private processes operate independently through a workflow engine. In our prototype system, public processes were described in BPEL standards, and private processes in XPDL standards. In addition, the interaction between two subsystems, WFMS and BPMS, is translated into Wf-XML messages. The interaction procedure and message exchange among these two subsystems and message handlers is illustrated in Fig. 10. If a *Request Order Process* of the customer is initiated and a purchase order (PO) is created according to the agreed format, the workflow engine of the customer sends a Wf-XML message with the PO. Then the message handler executes a service operation to the BPM engine, and the *Purchase Process* is instantiated in BPMS. The BPM engine then enacts the public process according to the specification of *Purchase Process*. In the next activity of the public process, the BPM engine recognizes its service operation, and finally translates the operation to Wf-XML message and sends it to external workflow engine of the supplier. Successive interaction between the two subsystems proceeds in the same way.

Fig. 11 shows user interface for customer workflow in our prototype system. The customer can initiate, monitor, and administrate private processes in the web interface. The workflow processes execute interaction procedure with external workflow processes according to the BPM engine of our system.

The example of the *Multi-Phase Process Composition Approach* demonstrates that executable private processes and contract public processes are independently defined, and then merged with each other for the purpose of business collaboration. The approach offers several advantages in the management and maintenance of workflow processes: reusability, independency, and flexibility. A company can reuse common workflows in the case where internal processes with different partners are identical. Moreover, the company can modify some of its workflow with independent public processes, if the change is not related to the protocol. Finally,

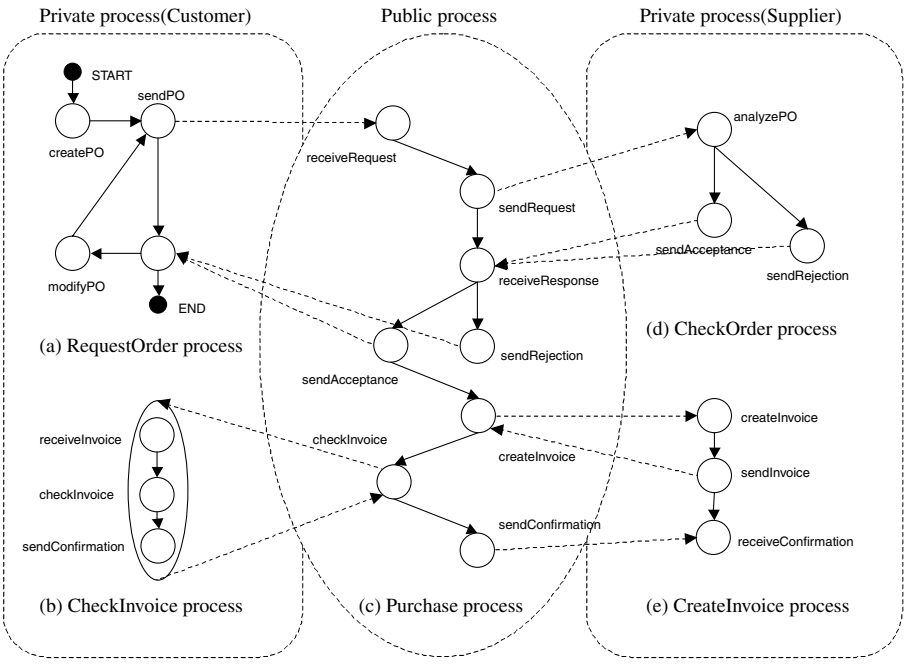

Fig. 9. Example of purchase order process.

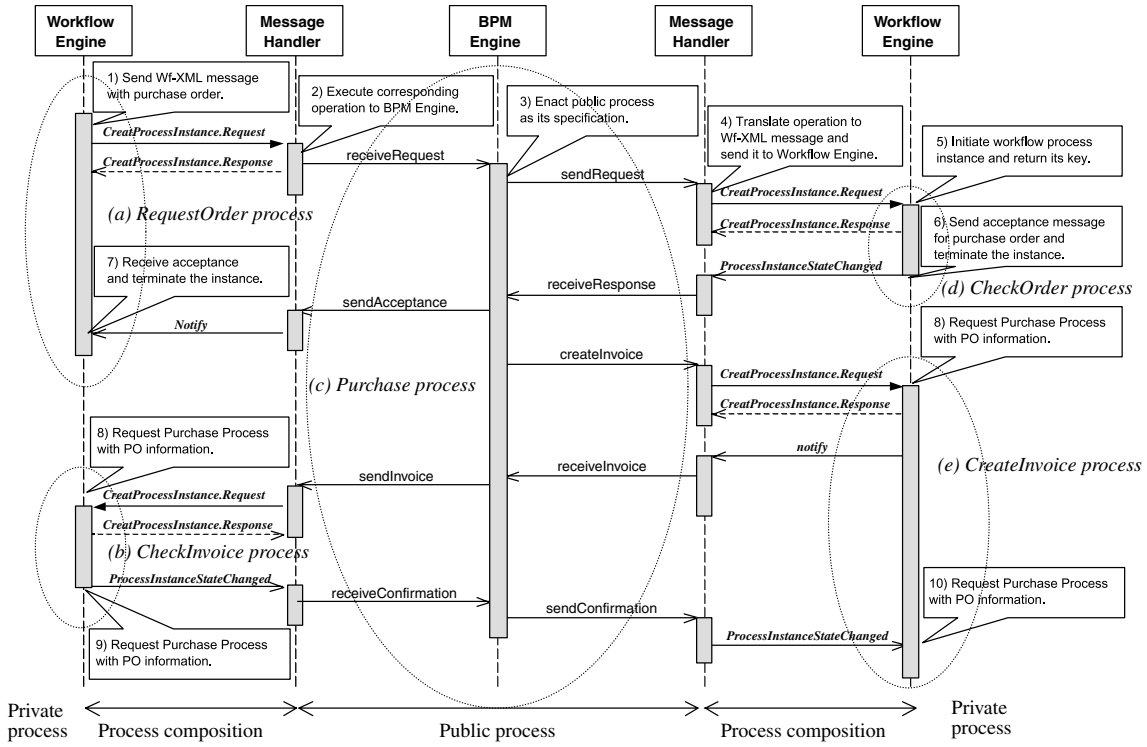

Fig. 10. Interaction procedure of process composition for purchase order process.

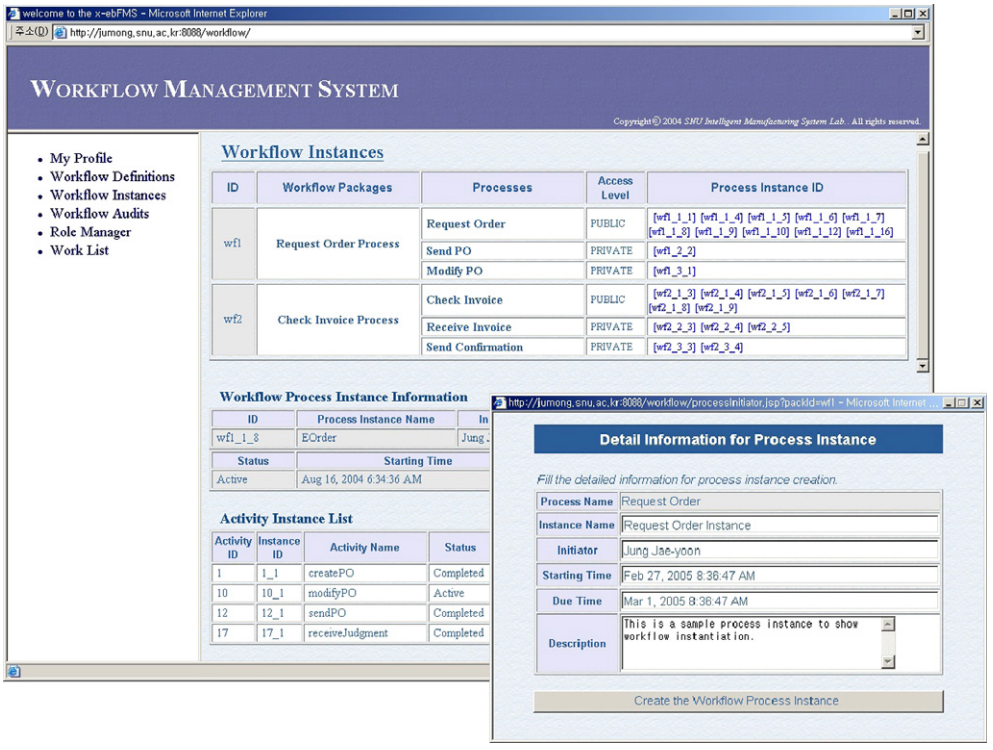

Fig. 11. User interface of the prototype system.

depending on the circumstances, the company can collaborate flexibly with trading partners by adopting appropriate public process languages.

6. Conclusions

Workflow is a core technology of business process integration. A variety of attempts of B2B process integration adopted workflow technology and proposed cross-enterprise frameworks to realize electronic commerce, supply chain management, and virtual enterprises. Moreover, web services technology has changed system architecture of business process integration, as well as e-business application integration.

This paper has focused on design and implementation methods for B2B process integration based on workflow technology and several related standards. We have presented a B2B Workflow Reference Model with three interfaces and requirements of workflow integrations. In addition, we have proposed three approaches to B2B workflow integration to implement process integration among business partners in an effective manner. These approaches are the Workflow System Interoperability Approach, *Web Service Choreography Approach, and Multi-Phase Process Composition Approach*. Our prototype system adopted the last approach and was developed with the BPEL and XPDL business process languages as well as with the interoperability standard, the Wf-XML messages. The *Multi-Phase Process Composition Approach* offers independent management and maintenance due to their separate process enactment.

These three approaches and the system we have suggested in this paper can provide the outline for the design and implementation of B2B workflow integration. This research will help potential implementing companies understand the related standards and technology, and will also help them implement the B2B workflow integration that is appropriate to their e-business environments.

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