Cross Organizational Workflow Management Systems

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1. Introduction

In the global market scenario engineering organizations can no longer afford a horizontal focus of doing everything in house. In order to stay competitive they must remain focussed on their core strengths, maintain momentum in the marketplace and outsource rest of the work to partners who specialize in those areas. Thus collaboration has become a strategic business imperative to stay competitive in today's market. With the advent of technology, organizational boundaries have collapsed making collaboration even easier, however collaborating organizations need a strong foundation to manage complex workflow spanning across the participating organizations called Cross Organizational Workflow (CoWf). Having achieved improved internal business processes by leveraging the technologies the manufacturing industry is now focusing on improving the collaboration efficiency by improving CoWf. Research is being carried out to address CoWf challenges and to evolve standardization in processes, data structures, interaction protocols by various groups like Object Management Group (OMG) and Workflow Management Coalition (WfMC) and others.

Manufacturing organizations have leveraged Product Data Management (PDM) systems to manage their product data and intra-organizational workflow. Now in collaborative environment, these systems need to address CoWf. PDM systems and related technologies are also evolving in line with the on-going research.

This paper reviews the research done in the area of CoWf. Various CoWf challenges viz. distributed process definitions, enactment of processes, heterogeneity between organizations in terms of different processes/standards, different software/hardware platforms, contracts between organizations, provision for autonomy for local decisions and individual security requirements in PDM systems context are analyzed. This analysis is presented as the requirements for evolving PDM systems. In the end this paper discusses the architectural framework to establish CoWf between heterogeneous PDM systems.

2. Collaboration Challenges

Though collaboration is found to result in overall cost and time-to market benefits, achieving an efficient engineering collaboration still remains a challenge. The participating organizations may be globally distributed and may need to communicate, co-ordinate and exchange product data on a continual basis. The need is for a system that provides required software architecture to support engineering collaboration. Such a system should enable contract management, ability to exchange product data between participants in real-time basis, provide local autonomy to define own processes, provide security on data that is being transferred, manage workflow that spans the organizations and control and audit the data-flow and its access.

Various products that are available in the market today address these requirements in part but fail to provide a complete solution. Standardization is the key by which systems can become interoperable and together provide a collaboration solution. Groups like WfMC and OMG have published such relevant standards for product vendors, some of which are reviewed here.

3. Related Research

Research related to workflow, its' standardization, interoperability and contract management has been reviewed in this section.

3.1 WfMC Research

The WfMC has been established to identify and develop appropriate specifications for implementation in workflow products. Since 1993, the WfMC has produced a number of specifications, mainly an interface model together with interface specifications for workflow management systems [1,2,3,4]. It is intended that such specifications will enable interoperability between heterogeneous workflow products and improved integration of workflow applications with other IT services. This should improve the effective use of workflow technology within the IT market for the benefit of both vendors and users of such technology. The WfMC workflow reference model is depicted in figure 1.

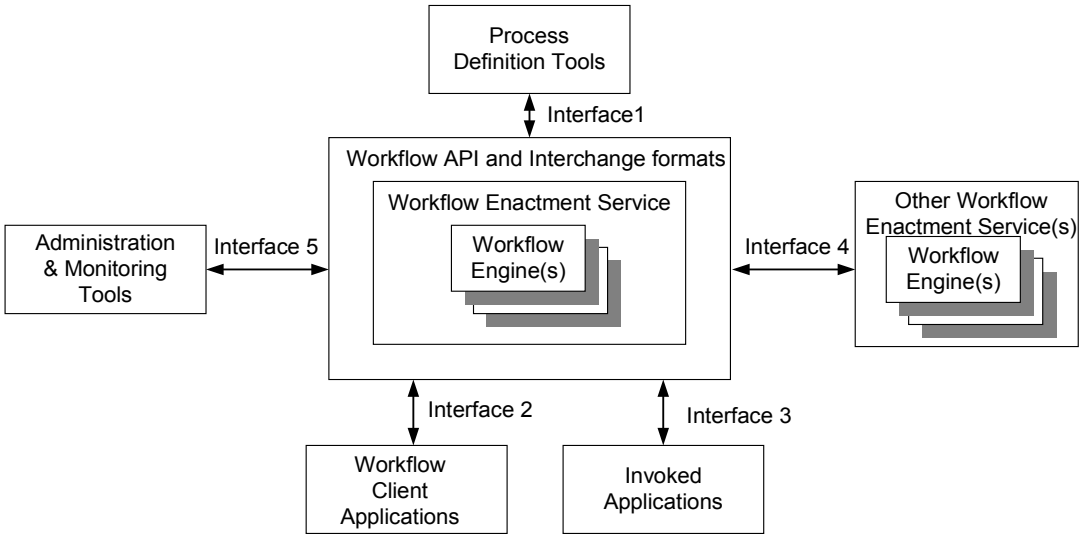

Figure 1- Workflow Reference Model – Components and Interfaces

Components

The Process definition tool is used to create the process descriptions. Workflow enactment services interprets the process description and controls the instantiation of processes and sequencing of activities, adding work items to the user work lists and invoking application tools as necessary. This is done through one or more co-operating workflow management engines, which manage(s) the execution of individual instances of the various processes.

Interfaces

The WfMC has identified five functional interfaces [4] to a workflow service, which are as follows.

1. *Workflow Definition Interchange (Interface 1)*
   The interface between the modeling and definition tools and the runtime workflow management software is termed the process definition import/export interface.

2. *Workflow Client Application Interface (Interface 2)*
   This interface spells out the details of a set of APIs named the Workflow Application Programming Interface (WAPI), which may be used in a consistent manner for access from a

workflow application to the Workflow engine and worklist, irrespective of the nature of actual product implementation.

3. *Invoked Applications Interface (Interface 3)*
   This interface is intended to be applicable to application agents and applications which have been designed to be "workflow enabled" (i.e. to interact directly with a workflow engine).

4. *Workflow Interoperability (Interface 4)*
   The Workflow interoperability interface defines the mechanisms that workflow product vendors are required to implement in order that one workflow engine may make requests of another workflow engine to effect the selection, instantiation and enactment of known process definitions by that other engine. The requesting workflow engine should (optionally) also be able to receive back status information and the results of the enactment of the process definition.

   Levels of interoperability:
   The Workflow Management Coalition identifies eight levels of interoperability [2]. The levels are distinguished by the architectural and consequent operational characteristics of implementations of workflow engines. The levels of interoperability are:

   Level 1: No interoperability
   Level 2: Coexistence
   Level 3: Unique Gateways
   Level 4: Limited Common API subset
   Level 5: Complete workflow API
   Level 6: Shared definition formats
   Level 7: Protocol Compatibility
   Level 8: Common Look And Feel utilities

   The level 4 of interoperability is of special interest since it is at this level that a workflow management system internal to a PDM system can work in tandem with a standards compliant workflow management system. This is the minimal level of interoperability that would enable integration of PDM systems into the workflow framework.

5. *Administration & monitoring Interface (Interface 5)*
   This interface would be an independent management application interacting with different workflow domains, capable of managing various functions across additional (heterogeneous) workflow domains.

3.2 Contract based Transaction support

An effective collaboration solution should address dynamic service outsourcing and contract based service specification. A detailed service specification stated in the contract forms the basis for a tightly linked co-operation implementing service provision from service provider to service consumer. Efforts towards the standardization of contract definition have resulted in a Contract Definition Language (CDL) which is expected to evolve into a universally accepted mechanism to incorporate dynamic contract based transaction into the engineering collaboration scenario.

CrossFlow – a European research project addresses the requirement of contract based transaction by providing Contract Making and Contract Enactment services [5]. The contract making service uses a contract template to search for a service provider via a trader. When a match between consumer's requirements and providers offer is found, a contract as per the template is created. Based on this contract a dynamic contract and enactment service architecture, which governs the transaction between the participants in the collaboration, is setup.

3.3 OMG Research

Workflow

OMG's goal is not only to promote the use of object technology in general but also to define and standardize on a common architectural framework across heterogeneous hardware platforms and operating systems called the Object Management Architecture (OMA). Since 1995, the OMG has followed the plan to extend their reference architecture with a component that supports workflow management [6].

Architectural context

In contrast to the WfMC's reference model, workflow management is not the focus of attention within the OMA but only one of its components. Thus, the Workflow Management Framework (WfMF) will have to smoothly integrate with other parts of the OMA.

Mandatory Requirements

The WfMF should provide interfaces for the manipulation and execution of workflow instances. This requirement is made more precise by introducing some groups of interfaces:

- *Workflow Metamodel*: A complete semantic definition of a workflow metamodel.
- *Workflow Enactment*: As the most central requirement, this requirement asks for a set of interfaces and their semantics to manipulate workflow objects.
- *Workflow Monitoring*: The WfMF should define interfaces that allow querying the status of running workflow instances.
- *Workflow Audit Trail*: These interfaces will support the retrieval of the history of workflow execution.
- *Nesting of workflows*: Workflows may be functionally decomposed.

PDM Interoperability

For the PDM systems to be interoperable they have to be based on the standard data model. Object management Group (OMG) Manufacturing Domain Task Force has done lot of work in the development of PDM schema and PDM Enablers.

STEP PDM Schema is the data model capable of supporting a central, common subset of the data typically managed within a PDM system. The intent of the STEP PDM schema is to provide, from a STEP community, a single schema along with the consistent mappings into that schema supporting core PDM capabilities. These enables PDM vendors to implement STEP based PDM capability. Once based on the PDM schema that implementation will be interoperable with implementations based on the relevant STEP application protocols.

The PDM enablers are standards based application programming interfaces that make PDM services available in CORBA environment to other systems that require them (such as PDM, CAx etc.)[7]. The enablers constitute the model of PDM interfaces that can be mapped to the available PDM systems. The federated PDM proposed by OMG enables collaboration and information sharing between internal organizations that may or may not be widely dispersed, teaming partners, suppliers and customers.

STEP PDM schema and PDM enablers address the data sharing, data integrity and data synchronization aspects in PDM environment. The PDM systems can evolve based on these

industry standards such as STEP PDM schema so that interoperability among PDM systems is ensured. These systems can provide interfaces based on these data models.

4. PDM Requirements

Distributed or federated installations of homogeneous PDM systems do allow collaboration among geographically dispersed participants but these are constrained by the need to have homogeneous systems. Evolving PDM systems need to implement the interoperability standards to enable collaboration using heterogeneous PDM systems. Requirements for Collaborating PDM systems are discussed below.

4.1 Application Data transfer

In engineering collaboration PDM systems need to exchange product data. This data may contain geometry data defined in CAD systems, specifications in the form of documents and other related data in the form of objects and attributes (Metadata). All such data needs to be interoperable with the equivalent applications at the receiving organization. PDM systems should address these issues at inception, either through the application of data standards or through the use of data translation tools that provide a seamless transition of data between two seemingly incompatible data structures. Focus here is the compatibility for exchange of metadata. This requires that heterogeneous PDM systems should have uniform data models for efficient data exchange. OMG STEP PDM schema and PDM enablers discussed earlier address the data sharing, data integrity and data synchronization aspects in PDM environment. For effective engineering collaboration heterogeneous PDM systems should conform to STEP PDM schema standard. Current PDM systems are still far from achieving this kind of interoperability.

4.2 Workflow interoperability

Workflow management capabilities that are available with the PDM systems are used primarily to define and manage automation of work internal to enterprises. In engineering collaboration environment workflow span across the participating organizations. Controlling organization needs to have an integrated view of this workflow. This requires exchange of workflow information between the two organizations that may be using heterogeneous workflow systems. To facilitate this kind of seamless interoperability, the workflow systems should have a standard way of defining and enacting the workflow. Since none of the existing PDM systems provides a standards based workflow support, their being able to participate effectively in an engineering collaborative workflow would entail an enormous amount of modification to the system. An alternative to this is to provide them with an interface to standards based workflow systems for interoperability. Conformance to WfMC's level-four interoperability requirement is essential for this interface.

4.3 Auditing

As discussed earlier PDM systems need to be WfMS compatible or should support the compatible interfaces [1]. For this compatibility, an auditing functionality that would keep track of the events in the process is required.

The audit information can be utilized for both analysis and derived status information. The workflow analysis tools will want the information presented in a consistent format, representing all events that occurred within a given set of criteria, such as, how long did process 'x' take, what activities have been performed within a given process instance? What the current status is of a given process instance? To understand where the process really is, the audit information measured against the process definition can provide an indication of the true state.

4.4 Contracts

In engineering collaboration, the contract should specify exactly the product or service to be exchanged in such a way that Original Equipment Manufacturer and its engineering partner know what they can expect and what is expected of them. The contract establishes the rules of the engagement. In case disagreements occur, the contract should ultimately contain the information to judge who is right [8]. In order to have contracts that can be used as a basis for automatic co-operation, these have to comply with several requirements:

Structured and complete contents: The contract must be searchable and interpretable by electronic systems. This means the contract must have a clear structure and use unambiguous naming conventions.

Flexibility: The contract must be flexible with respect to usage and reusability. The contract should also be flexible with respect to the enactment characteristics, allowing adaptation of contracts to organizations and circumstances.

Heterogeneity: The contract should be interpretable by each WfMS that is on the market. The contract should therefore be stated in terms that have meaning to each type of WfMS. Each kind of WfMS must be able to map the contract view on the process to its own process specification language.

Encapsulation: The contract should hold an encapsulated view on the process, with enough information to be meaningful to the consumer without containing irrelevant detail or private information of the provider.

Legality: The contract should be a legally binding document that defines the co-operation between the companies. In case of conflict the contract should contain the information for settlement [10].

4.5 Autonomous Decisions

Any enterprise that becomes a part of an engineering collaboration depends on its own processes to manage work internally. These process definitions are traditionally managed in the PDM workflow systems, which in the collaborating scenario will be used externally by participating organizations. In the highly dynamic environment of the engineering collaboration, enterprises need be alert to the flux in market and be able to reposition themselves with minimal response times. A key to maintaining the competitive advantage for any enterprise hence becomes the adaptive ability of their processes. This necessitates the internal systems of an organization to be able to manage and modify the process definitions and enactment strategies for these processes without affecting the collaboration. This allows them to leverage the inherent capabilities of the PDM systems to manage and enact workflow and leaves room for process improvement initiatives internally.

4.6 Security

Security is major concern of any model for establishing a cross-organizational workflow and data exchange. In the collaborative environment, PDM systems will have following requirements.

- Selective exposure of data across organizations or geographies
  As cross organizational workflow systems span over traditional organizational boundaries it becomes necessary that such a system should provide the participating members with a mechanism to selectively conceal and disclose data in whole or parts to the other participants in the collaboration.
- Security for data transfers
  Standard cryptographic techniques and secure layers for data transfer should be utilized for securing data in transit.

5. Proposed Architecture

In this section, the architecture to support cross-organizational workflow between organizations using PDM systems is presented. Most of the PDM systems of the present have workflow management systems but none of them have matured to the level where it can be used for seamlessly integrating applications from across the organizations in the extended enterprise. It is in this regard that a standards based workflow engine at global level should be used to support workflow definition and enactment service.

The native Workflow Management System should be used to define the business processes of individual organizations and serves as a means to maintain the autonomy of the organizations on their business process definitions. It would also enable the enactment of the workflow internal to PDM and trigger the messaging processes at predefined points in the flow for enabling information flow back to the global workflow management system.

The various element of the proposed architecture are explained below.

5.1 Workflow Server

The Workflow server hosts the workflow services for process definition, auditing, and enactment. Adapter services would be used to interface with systems such as the Document management systems, the Directory services, Back end applications like PDM and Database systems. The workflow server provides all the functionality for defining, enacting and auditing workflow.

5.2 Adapters

Component-based adapters can be used to aid the server functionality. Integrating other back end applications to the global workflow management framework requires the construction of adapters. These adapters abstract the details of connecting to the back end systems and they should be able to interact with the workflow server with a published set of APIs. Developing such component forms the central activity in an effort to integrate PDM systems into the global workflow system.

5.3 Clients

The system would provide clients for enabling definition, administration and enactment of the workflow. These clients run on industry standard browsers and provide a mobile access to all the functionality available with the server.

5.4 WfMC layer

The Workflow Management Consortium has specified the inter-operability standards to be followed by workflow management systems and has defined different levels of conformance to the standards. To enable an integration of the PDM systems into a cross-organizational workflow system mandates the existence of an interoperability API set to be available with the PDM systems that can be used by the workflow management system that manages the cross-organizational workflow.

At present none of the PDM systems provide this kind of interoperability since their workflow management support is totally contained in the native application and is not designed for

collaboration. But most of them do provide their own native API set which can be leveraged to construct a layer confirming to the WfMC standards above the native application. [2] Such a layer would implement the APIs as specified in the WfMC standards for interoperability between workflow systems. It is through this layer that the adapter services in global workflow system for the PDM applications would use the workflow capabilities of PDM products.

Development of a standards based layer for the workflow management system lets the PDM adapter at the server end to connect to the back end PDM systems in a PDM neutral way and enables easy addition of PDM systems into the framework.

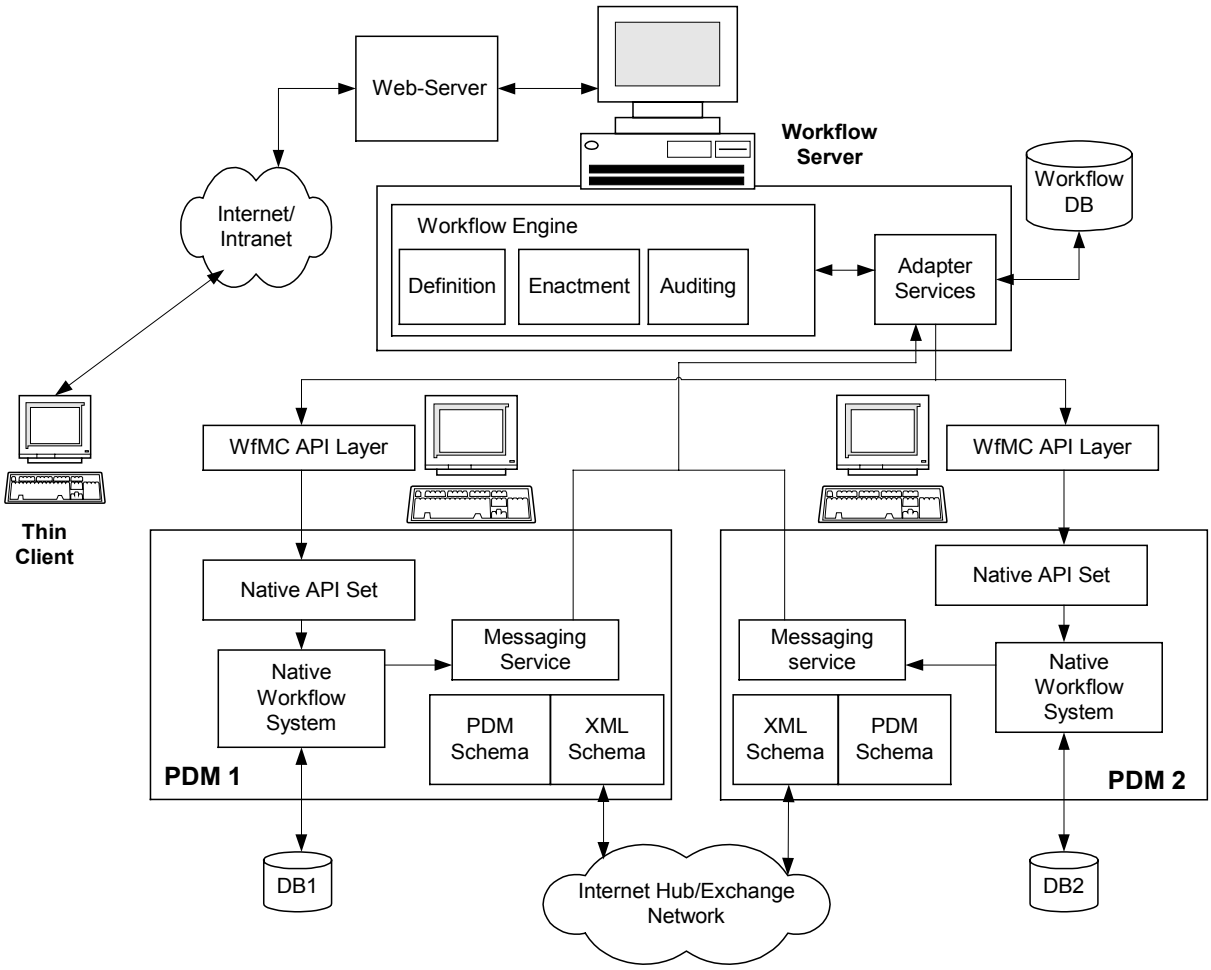

Figure 2- Proposed Architecture

5.5 Messaging service

This mechanism provides a means for the PDM systems to connect back to the workflow adapters when any state changes occurs in the PDM system to the work items transferred to it. The adapters would in turn retrieve workflow data from the PDM systems and execute the desired business logic abstracted into it thus completing the transaction loop. Messaging service has to be in the interoperability level 4.

5.6 PDM Interoperability Service for Product Data Transfer

While trying to incorporate systems like PDM into a workflow frame work one should clearly demarcate the kind of data that is meant to be handled by the global workflow system and the back end PDM systems. Due to their inherent capabilities these two systems (PDM and global workflow systems) differ greatly in their approach to handling data. Workflow systems concentrate on process data while PDM systems focus primarily on product data. To preserve the advantage of PDM systems in their ability to handle product data in a more effective manner it becomes necessary to let the PDM systems control the product data transfer that would be initiated by the global workflow. Recent experiments in "PDM interoperability" have established the feasibility and effectiveness of enabling PDM interoperability through standardized schemas and a web based distributed architecture. The PDM interoperability enables product data exchange through the use of open systems, which adopt neutral standards information models and semantics with the help of STEP PDM and XML schemas. Web infrastructure utilizing the neutral standard information technology powered by XML and Java forms the distribution backbone of the service. Efficient accessible and secure data transfer will be ensured by employing Internet/ANX [9].

6. Conclusion

The Cross-organizational workflow management system plays an important role in improving collaboration efficiency. The research done in the area of workflow interoperability and electronic contract is presented in this paper. The requirements of the PDM systems to address the workflow interoperability are discussed. The future PDM systems should support data transfer management based on uniform schema, along with workflow definition and enactment, auditing functions, contracts, new security requirements and a standards based interface to workflow systems. In engineering collaboration, successful CoWf implementation should have strong foundation of PDM interoperability and workflow interoperability between collaborating engineering partners. The PDM interoperability is essential for product data transfer required in workflow. Inter-operability between native workflow systems provided by PDM systems can be based on WfMC standard. This will ensure the interoperability of PDM products with WfMC compliant applications. The architecture for enabling engineering collaboration has been presented in this paper and experimentation is under way.

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