A Flexible Web-Based PDM Approach to Support Virtual Engineering Cooperation

Michael Abramovici, Detlef Gerhard
Ruhr-Universitaet Bochum
Information Technology in Mechanical Engineering (ITM)
44780 Bochum, Germany
{abr, dege}@itm.ruhr-uni-bochum.de

Abstract

The objective of the work presented in this paper is to provide a methodology and tools for distributed PDM environments especially suited for virtual project based cooperation in engineering design. A research project called WebFlex-PDM (Web-enabled Flexible PDM federation) is introduced. This project mainly deals with extensions to existing PDM systems to provide the capability for easy integration into different PDM environments of cooperation partners and to enable use of various geographically dispersed WWW-based engineering information resources. In order to analyze the requirements for a flexible management of distributed engineering information resources the paper first describes an application case study. The requirements are compared to the state of the art of distributed PDM solutions and the existing deficits are shown. Finally the main ideas, the architecture, and prototype modules of the WebFlex-PDM approach are presented.

1. Introduction

Increasing product complexity, growing competition, emerging globalization, and stronger customer focus force the majority of enterprises to network their own geographically dispersed sites and to extensively cooperate with customers or suppliers [1]. Such cooperation has generally been in the production area, with the main goal to cover and serve global markets and reduce overall product costs. In the last few years cooperation within product development, design and engineering has become increasingly important, since products have become more complex and require distributed, cross-functional, and cooperative product development. Prognoses of the automotive industry [2] forecast a reduction to about 10 worldwide operating global combines of automotive manufacturers which forces distributed product development processes and optimal usage of all worldwide available product development resources.

The latest developments of information and communication technologies establish a platform for worldwide cooperation and collaboration within engineering since the problem of geographical and time related distance nearly disappears. This platform offers new opportunities especially for small and medium sized enterprises (SME), freelance engineers, and teleworkers to build a project based alliance or a so called virtual cooperation [3] and thereby maintain competitiveness within the global market.

Distributed product development processes within virtual cooperation on the other hand require extensive use of advanced information technology (IT). Especially important are process support, management of product data, and management of additional engineering information among involved partners. For these tasks PDM systems have been successfully introduced in engineering design departments over the last years. They are capable to manage data generated by a variety of applications (CAD, CAE, DTP, office, etc.) in a pragmatic way using the so called metadata concept. Metadata contains classifying, descriptive, or attributive object information. This information is used to handle and manage associated user data and stored within the PDM system's database. User data, e.g. CAD files or office files, is stored on file system level within so called electronic data vaults or as binary large object (BLOB) in the database without having direct access to internal contents (black box integration).

PDM systems in general cover the following groups of application specific functions in addition to general functional capabilities like user management, access management, and data visualization [4]:

- **Document management** of electronic as well as of conventional documents includes user access control, check-in/check-out functionality, status- and revision management, management of different file types, scanning, archiving etc.

- **Product structure and configuration management** enables product structure definition and control, BOM generation, management of product configurations along the life cycle, etc.
- **Part family management and part classification** contains classification of parts and part families and provides query and retrieval functions etc.
- **Workflow and process management** covers the definition and control of workflows and information flows (e.g. engineering change procedures, release procedures), data transportation, etc.

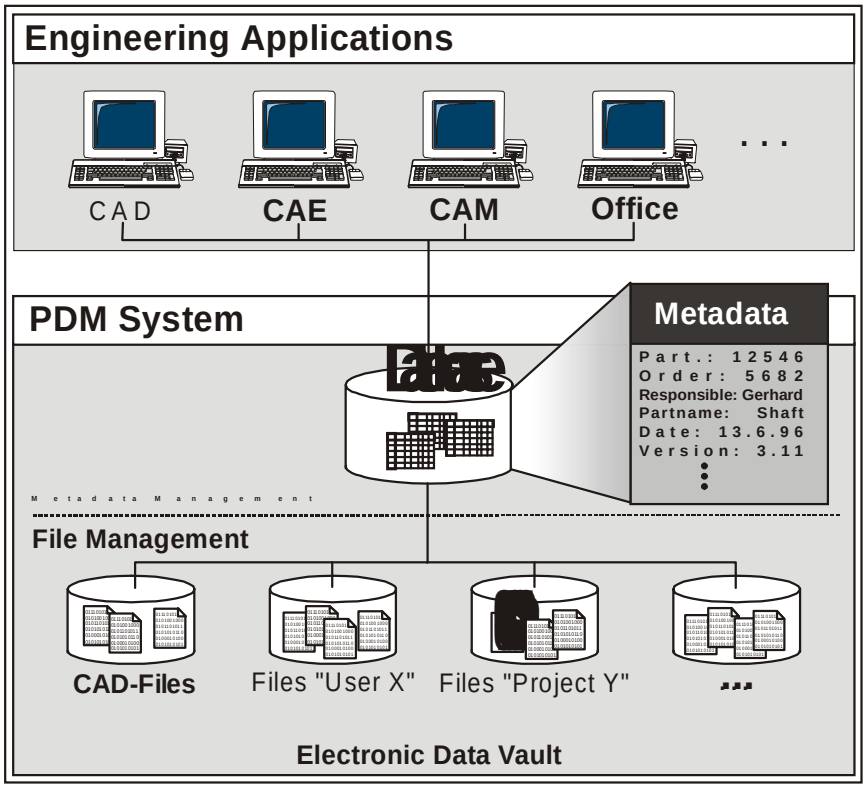

Figure 1. Metadata concept of PDM systems

The development of PDM technology today is increasingly driven by globalization issues and the majority of commercially available systems provides functions for distributed data management. Nevertheless, available distributed PDM-solutions supporting cooperative product development processes require homogeneous IT environments based on one single PDM system using one logical data model and uniform technical and administrative processes. They also require a significant implementation and customization effort, lack flexibility, and, in general, they are based on one single homogeneous PDM-system. For this reason, they are not suitable for a virtual cooperation because those are usually temporary limited, dynamic, and the involved partners have different organizational structures and IT-environments. Hence, available systems are not suitable and applicable for virtual cooperations because those are usually temporary limited, dynamic, and partners have different organizational structures and IT-environments. Furthermore emerging Internet-based information resources [5], e.g. electronic product catalogues, standard parts libraries, patent information databases, which provide value aided services to efficiently support product development tasks, especially within virtual cooperation, are not considered adequately. Due to these boundary conditions there is a need for further development or enhancement of PDM-systems.

2. Application Case Study

To express the requirements of virtual cooperation concerning overall distributed information management, in the following an application case study of technical product documentation (TPD) processes as part of engineering design tasks is discussed. The findings of this case study are on the one hand results of a project with an industrial partner, a special machine-tool manufacturer,

and on the other hand based on a survey conducted within the VDMA (Verband Deutscher Maschinen- und Anlagenbau/ German machinery and plant manufacturers association) working group "technical product documentation". The goal was to find out the requirements for data or information management within engineering processes in a heterogeneous cooperative environment as a basis for the development of a concept to improve information management issues within TPD departments.

TPD entails processes like generating or editing user manuals, maintenance and service handbooks, product information sheets, etc.. TPD is not one of the core processes within product development but nonetheless even as an ancillary process it can be the critical path concerning time-to-customer, since manuals etc. are mandatory for each delivered product even if the customer is internally within the same company. Therefore TPD often requires simultaneous engineering parallel to core processes of mechanical design, electric/electronic engineering design and manufacturing/assembly. Due to new regulations and laws within the context of the European Community and particularly because providing online information of goods and services on a company's WWW-homepage opens new opportunities for electronic commerce, TPD becomes increasingly important as an integral part of the product development process. TPD processes are often conducted as virtual cooperation. Main characteristics are very interdisciplinary tasks and the extensive need for department-spanning sharing of information in different semantic contexts (figure 2).

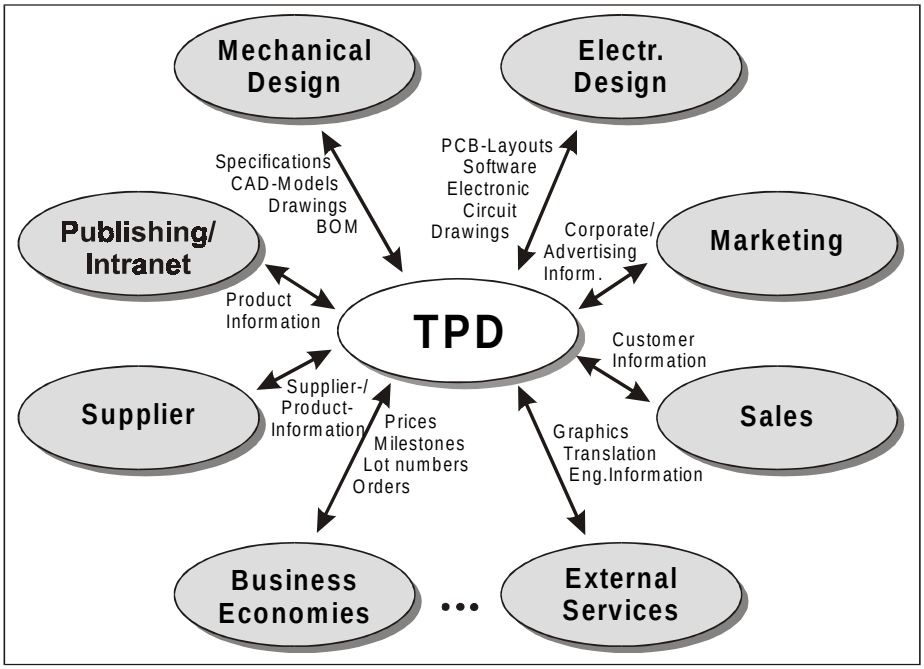

Figure 2. Information flows within TPD processes

Additionally to the information located or originated at different cooperation partners, a lot of information from third party engineering information resources, increasingly provided through WWW, has to be handled and managed, for instance standards, guidelines, patents, laws, literature, etc.. This information has to be linked to product and process related information in order to have a comprehensive documentation.

Major observations of the application case study or survey are as follows:

- A lot of different partners and departments are involved in TPD processes, e.g. core mechanical and electric/electronic engineering design departments, translators (internal/external), photograph or graphics agencies, marketing (corporate design), sales, online-publishing (multimedia-documentations, online product presentation).
- Technical documentation/publishing departments are in most cases separated from the design departments and use different IT-infrastructures and applications. Therefore the data vaults are usually separated from each other though the represented information is quite similar and contains a lot of interrelationships.
- Collection and editing of different kinds of information is the main task and requires about 60-70% of the

overall work. Additionally information of supplier components has to be added.

- About 60-70% of the needed information for TPD is already available in different departments or from suppliers, cooperation partners etc. but in a different semantic context.
- Most of the information is not available explicitly e.g. in form of models (CAD, database, etc.) but implicitly in different kinds of documents, electronic as well as paper. Therefore human interpretation and extraction is necessary to take into account the different views according to the tasks of the involved partners.
- The documents can be published in paper form and in electronic form, offline on CD-ROM as well as online on the company's WWW-homepage, engineering marketplaces such as GEN, etc.. This leads to considerable requirements concerning data management.

Even though this case study does not include all aspects of worldwide virtual cooperation in engineering design it eminently mirrors main characteristics concerning requirements to PDM solutions and therefore one can transfer demands to other processes.

3. Requirements

General requirements of data management are accessibility, integrity, security, efficiency of storage and flexibility. The analysis of the application case study leads to the development of specific requirements for distributed PDM solutions for virtual cooperation of engineering design departments. Those are:

- Department/enterprise-spanning transparency of data/information, i.e. transparent access to the product data of cooperation partners and other distributed engineering information repositories.
- Applicability within a virtual cooperation, i.e. due to the dynamic temporary and project-based character of virtual cooperation a fast constitution and dissolution has to be supported.
- Decentralized, adaptable PDM system architecture, since all partners are obliged to maintain their data and process management solutions and therefore rely on flexible, IT supported linking and interchange concepts.
- Focus on department or site individual demands because of very interdisciplinary tasks which need specific support and system capabilities.
- Administration friendly and easy to maintain client application to be distributed to different cooperation partners.
- Support and assistance for the user concerning gathering and handling data, query and navigation within a distributed PDM environment.

Virtual cooperation relies on the use of available IT infrastructure such as data networks. The Internet and the underlying technology plays a dominant role in this area. Always connected to the use of Internet as network infrastructure for business matters are issues like sufficient bandwidth and adequate security. Since this is a prerequisite for all applications in the context of electronic business, it is not mentioned here explicitly. Currently, there is a lot of research and development work ongoing in the area of virtual private network (VPN) technology. Since this is a promising solution for the mentioned problems, the resulting requirement is that distributed PDM solutions have to support VPN protocols.

4. Distributed PDM Solutions

Commercially available PDM systems to a great extend provide functions for distribution. There is always one single system environment with a hierarchical structure of sub-servers connected to one superordinated backbone server ensuring transactions. Furthermore, commercially available systems employ a classical 3 tier client/server architecture separating presentation level from application or business logic level and data level. Within distributed PDM solutions, distribution of metadata and user data has to be distinguished. Distribution of user data stored on file system level is commonly implemented using network file system capabilities whereas distribution of metadata requires more advanced solutions and often employs capabilities for replication or fragmentation of data provided by the underlying database management system (DBMS). All commercially available distributed PDM solutions have in common that a homogeneous environment based on one single PDM system with one single internal data model is required. Figure 3 shows a classification of different approaches for distributed PDM environments regarding the distribution of metadata and user data. They all follow a hierarchical system architecture, i.e. there is a main server with subordinated workgroup or site servers and clients but the overall coordination and transaction maintenance is centralized.

Several approaches to distribute metadata and bulk data are conceivable but only a few are reasonable because of database or network limitations. The most frequent solution within actual industrial applications is the distribution of user data with a central metadata storage. In this case, the user data can be both replicated, i.e. physically duplicated, and fragmented, i.e. physically divided. Since metadata compared to user data by far has a smaller volume, such a configuration offers a sufficient performance, particularly with a limited number of sites in a static enterprise structure with a fast network link. Some systems additionally allow the distribution of the metadata on different database-servers, which leads to a further

reduction in response times and in network load, but also to increased system complexity.

The main problem with distributed PDM solutions is the diversity of data models within the different sites corresponding to the specific data and processes. For virtual cooperation, as described in the case study, this PDM distribution concept does not meet the requirements concerning flexibility and implementation efforts. This is particularly the case if partners are SME, since SME in general do not have the capacity for extended PDM projects. A single homogeneous PDM environment in a this scenario is evidently not applicable because the involved partners might differ on project basis. The information handled within the different departments represents very diverse views and is originated not only in PDM systems of cooperation partners but also in different WWW-based engineering information sources. Especially within temporary limited cooperation the expenditures to establish an integrated distributed PDM environment would likely outweigh its potential benefits. Additionally the required time for setting up the environment would push a project start too far behind.

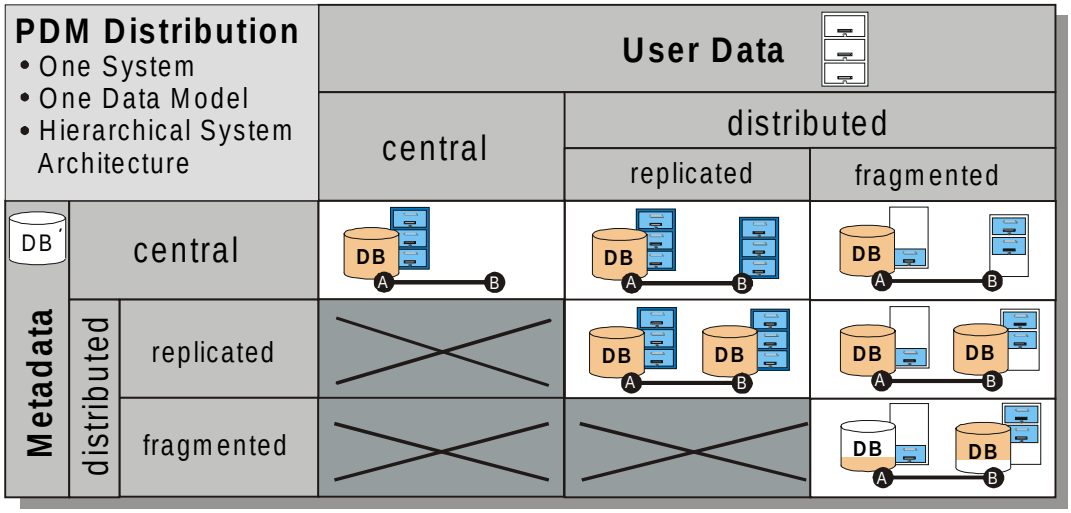

Figure 3. Classification of different approaches for distributed PDM

One way to face this problem is data exchange or data sharing between different PDM system environments. But, in contrast to other applications, there is no standardized or even proprietary unique PDM data format available, since each PDM implementation is a company or site specific solution with a customized data model. Nevertheless, different international standards have been developed in the recent years which provide sort of a homogenization in this area, e.g. ISO 10303-214 CC6 (STEP – Standard for the Exchange of Product Model Data, Application Protocol 214 Conformance Class 6), ISO10007 (Configuration Management), ISO 13584 (Parts Library), or PDM-Enablers Specification of the OMG (Object Management Group). The exchange of data between PDM systems occurs in form of so called data packages. A data package contains the metadata as well as the associated user data and transport information. Experiences and evaluations show that employment of the STEP standard is primarily suitable for long term cooperation within customer supply chains for instance whereas the OMG PDM enablers specification is a preferable approach for intra company integration different PDM applications.

Another approach for distributed PDM solutions is the so called federation of PDM systems. The federated concept bridges the gap between high degree of integration, which requires considerable implementation efforts, and manual information exchange, which does not provide the required support of effective engineering processes. Federated integration implies a bottom-up approach starting with existing solutions in different departments or sites. In many cases, the individual sites of a federation are autonomous and not interacting with other sites, but in case of a cooperation each of the subsystems provides a discrete portion of a cooperative solution as a whole. In analogy to a federation in a political context the subsystems adopt to certain agreements in order to achieve common benefits. Each of the systems within a federation remains independent from the others which is a significant advantage in case of network or server problems.

A similar concept has proven applicability within the evolution and development of the WWW. There is no integrated system, no overall unified semantic of data or information, very heterogeneous concepts concerning the way information is stored and presented. Nevertheless, the WWW is very successful because it is easy to understand,

to use, and to implement. It provides user assistance through search engines, notification services, catalogues, etc. and a basic level of standardization using standards as TCP/IP or HTML. Currently, very view PDM systems offer capabilities to implement a federated PDM solution and the functions have not yet matured. Employment of this technology within industrial applications is, if ever, only in pilot stage. One major problem which still exists, even in a federated system, is the difference within the semantic of information in different contexts. Therefore further development is necessary.

5. WebFlex-PDM Approach

Considering the requirements from the case study and experiences from examined and evaluated PDM applications [6], subsequently potential solutions are discussed. Due to the pragmatic approach PDM systems are basically a suitable approach for integration data and process management within heterogeneous distributed product development environments. PDM systems serve as an integration platform for different kinds of applications, they do not integrate all information on a semantic level respectively map all views in one single data model but they provide an effective mechanism to manage different kinds of models, documents etc. using meta-information.

The main task of engineers within the product development process concerning information handling is to gather, edit, and prepare different kinds of information for own purposes within the context of the department or company and make this information available to those who need it. Therefore, management of data explicitly has become a job of an engineer and has to be supported efficiently by tools such as PDM systems. This is especially a difficult task in a cooperative PDM environment.

In the following, an approach called WebFlex-PDM (Web enabled Flexible PDM-federation), which is currently subject of research activities at ITM-Bochum, is presented and explained. This research work particularly focuses on flexible integration of different PDM environments and use of different kinds of WWW-based engineering information repositories. Therefore, especially the demands of cooperative engineering design processes in virtual enterprises, as shown in the case study, are addressed.

The goal of the WebFlex-PDM project has not been the development of one more PDM system but the development of add-on modules to commercially available PDM systems providing functions for flexible and easy to implement integration for virtual cooperation in a federated manner. In contrast to other existing integration concepts for distributed engineering applications e.g. on data model level [8], WebFlex-PDM is an approach for an integration on user interface level.

A further objective has been the conception of a methodology to employ PDM systems within virtual cooperation of engineering design. The federated concept has been chosen because it fits to the requirements as stated above. One centralized superordinated backbone service for transaction monitoring, redundancy and consistency checking cannot be established since all subsystems have to remain autonomous and independent. Nevertheless, maintaining actuality and consistency data is a crucial task and has to be ensured for instance utilizing workflow mechanisms.

The main idea behind WebFlex-PDM is to optimally support the user by enabling an effective cooperative use of distributed and heterogeneous data resources, not the total automation of cooperative processes and data management issues. This approach entails several implications on the technology and on the methodology of working in such an environment or using it within projects.

5.1 Technological Implications

Figure 4 schematically shows the architecture of WebFlex-PDM. The standard PDM system consists of a PDM engine which provides the basic PDM functions, the underlying database containing metadata and user data. Basic PDM functions are e.g. document management, workflow management, or product structure management. A built-in HTTP server allows WWW based client access to the PDM system. PDM services are for instance visualization modules, data import functions etc..

As add-on to the standard PDM system there are the so called WebFlex-PDM modules which are several software modules for federation services and the assistant system. Federation services are for instance functions for administration and configuration of the federation e.g. specification of the systems belonging to the federation, user and access profiles etc.. The user profile oriented assistant system provides functions for navigation, utilizing a federated engineering information system environment, as well as for gathering, managing, and semantic mapping of information. These functions are for instance a data exchange assistant, a change notification mechanism to enable a controlled data redundancy and an automated monitoring of the consistency of data objects within distributed systems. Furthermore, a navigation and authentication support, a federated query assistant for distribution of queries from the local system to remote systems etc. A so called assistant system repository (ASR) persistently stores required information for the federation services and the assistant system.

As prerequisite, the commercial PDM system has to provide certain capabilities to implement the WebFlex-PDM modules. No standardized API or unified data model is necessary, but for instance a built-in HTTP-server to provide a standardized way to access the system, the ability that objects can be uniquely identified and accessed by a URL, and the ability to modify the data model to implement the ASR. Concerning implementation this approach requires the consequent usage of Internet technology, i.e. TCP/IP, HTTP, Java, HTML which serves as a basic level of standardization. Most of the available IT-systems within engineering environments offer interfaces to Internet technology. On this basis the adaptation of legacy systems and the implementation of additional services can be accomplished with comparatively less effort. As a result, an extensive independence from hardware and operating systems is achieved.

Within this research project, different application scenarios to be supported in a federated PDM environment together with other engineering information resources have been developed and analyzed. The test environment consists of different PDM applications a Web-based Standard Parts Library (Intranet) and several WWW information resources. For the prototype implementation of WebFlex-PDM add-on modules the Java based standard PDM system PTC Windchill has been used because the Web-centric concept of Windchill currently fits best to this approach. Windchill provides all functions needed to implement the add-on functions and has a built-in interface to standard CASE tools like Rational Rose and Symantec Visual Cafe object modeling and programming.

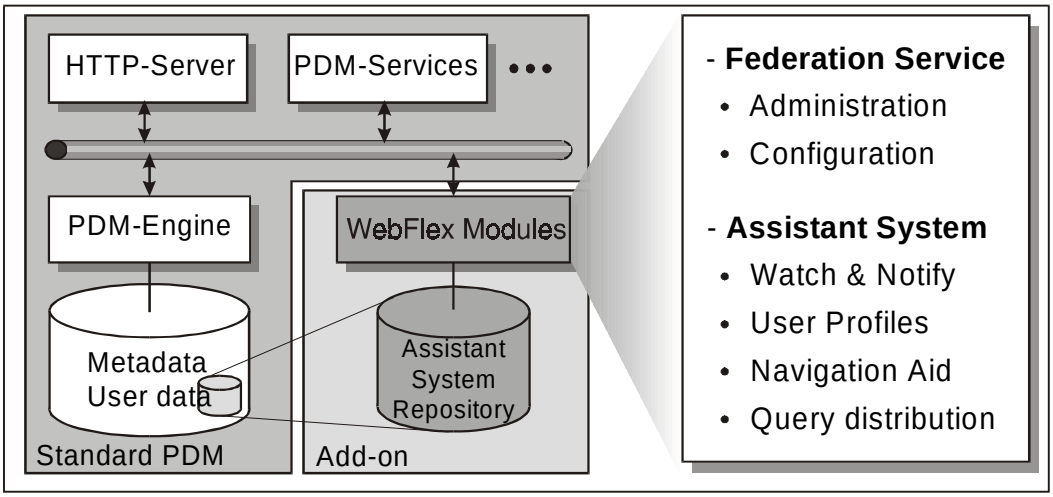

Figure 4. WebFlex-PDM Architecture

5.2. Methodical Implications

The way to employ WebFlex-PDM in a distributed engineering environment corresponds to the way to use the WWW. The PDM environment of each partner in a co-operation remains autonomously according to the federated principle. A distinction has to be made between a home system and a remote system (figure 5). A home system represents the context of a certain domain, i.e. the view of one site or department. It also provides user profile oriented assistant functions e.g. for navigation and query. Users mainly work in their home PDM environment but they can also access information on remote systems at distributed locations as a specified user with certain rights. This access is on user interface level unified and therefore transparent.

Queries and other user actions within a local PDM-system are dispersed to other systems of the cooperation or engineering marketplaces by the federation service of the local PDM system according to security mechanisms and a predefined setup. Information from remote systems can be linked to local information as a reference or stored locally in a different context which means data redundancy to a certain extend but also independence from other systems. Interpretation and semantic mapping has to be done by the user supported by the system, therefore semi-automated. Data consistency is not maintained automatically but the assistant system supports the user by a notification service. A data exchange assistant helps to transfer information from the remote system to the local system, e.g. editing metadata.

Mainly a so called pull principle is employed and supported by assistant functions. A demander of

information is responsible for managing this information within the home system in the context of the domain. Actions in a local system like update of information should be triggered indirectly by organizational means or workflow mechanisms not directly by a remote system via push technology. If, for instance, a notification service is provided by the home system, the solution is independent from the functions and capabilities of remote systems. Another advantage of this method is that remote PDM systems and other information repositories can be handled in the same manner. One application example might be that an engineer is going to redesign a specific assembly which contains standard parts from an WWW based engineering marketplace. The assistant subsystem monitors referenced objects by an agent and notifies the user if changes occur. The user has to decide whether to update that part with the new version, to use another similar part if changes in form, fit, function, etc. are made, or to maintain the old version if that part is still available in stock.

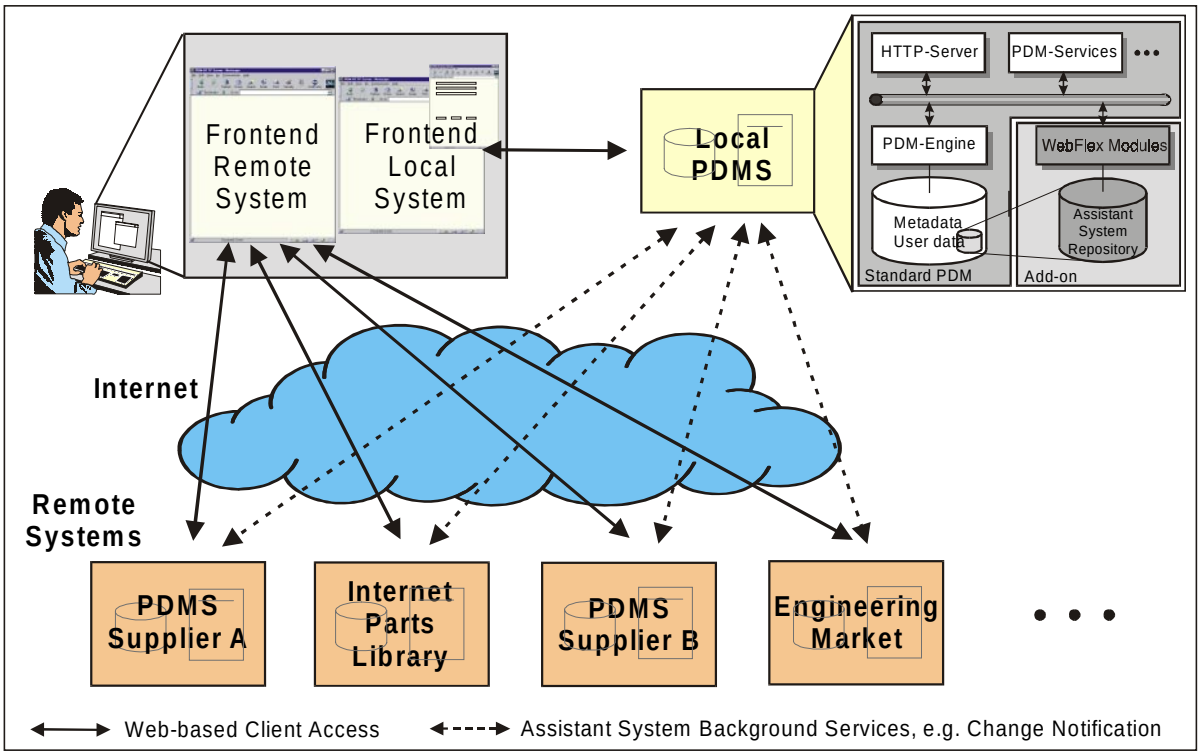

Figure 5. WebFlex-PDM application environment

5.3. Example Prototype Module

In this section, one of the developed WebFlex-PDM add-on modules is presented as an example. One major required function within a distributed environment is a data exchange capability between different PDM systems, since the different systems of a federation are not tightly integrated. Concerning data exchange, one challenging problem is the difference within internal data models and semantics.

To support this data exchange issue, one of the WebFlex-PDM modules is the data exchange assistant (figure 6). This is a module which allows an XML based data exchange of arbitrary product model data, such as product structures, part information and documents. For example, if a product development engineer of a car manufacturer needs information of a supplier module, one can connect to the supplier PDM system, extract the required data, store it temporarily on client side, and import it in the home PDM system. This process is supported by the data exchange assistant and allows the management of metadata, user data and relationships in a site specific semantic context. A user once has to define a mapping rule between objects and attributes, represented by different XML document type definitions (DTDs). This information is stored persistently in the ASR and thereby available for further data exchange procedures. User data can either be stored within the home system as a copy or as a reference to another engineering information resource using a uniform resource identifier (URI).

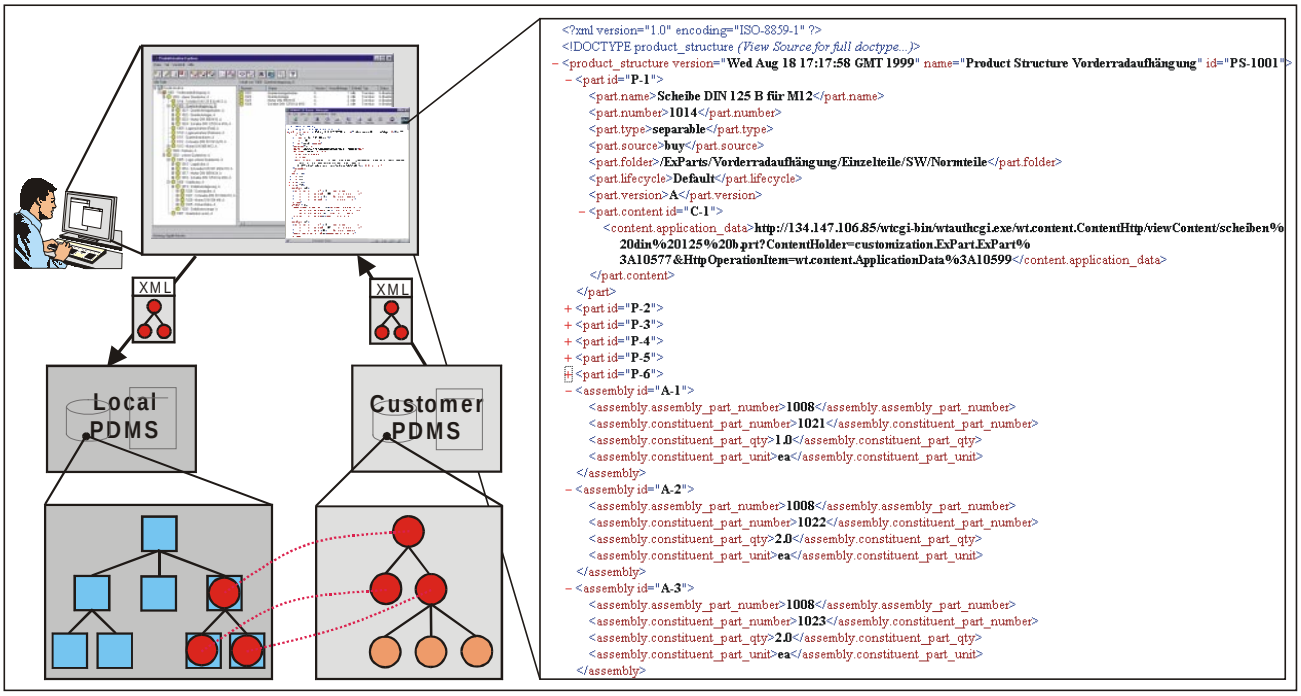

Figure 6. Data Exchange Assistant

6. Conclusion

The requirements from the case study are addressed properly with this approach. WebFlex-PDM provides enterprise-spanning transparency of heterogeneous information, a decentralized and adaptable PDM system architecture, as well as support and assistance for the user concerning gathering and handling data. The Web centric concept of Windchill as underlying PDM system ensures applicability within virtual cooperation through scalability and flexibility and administration friendly and easy to maintain clients. The next steps will be to finish a prototype functions and perform a pilot implementation within an industrial environment for evaluation and verification.

The main benefit of the introduced approach is the increased flexibility within a loosely linked federated IT-environment while each of the department-oriented PDM solutions remains independent from the others. They remain "small and simple" and focused on the specific tasks of that particular department concerning functions, data model, etc.. Another advantage of the approach is that different kinds of information systems (EDM, PDM, MRP/ERP, Engineering Marketplaces, legacy databases, etc.) which all provide different functions can also be linked to the federation. Almost all commercially available PDM systems provide a built-in HTTP-server for a standardized web access. The most recent ones like PTC Windchill even employ Internet technology with all the available services (e-mail, search-engines, etc.) as system foundation.

The presented approach is not a replacement for other approaches supporting distributed PDM solutions, but focussed on virtual cooperation. Available distribution technology within commercial PDM systems provides a closer integration for distributed sites of one enterprise, if a homogeneous solution can be established. Use of standards, such as STEP AP214 CC6, can be a promising approach for established and proven customer supplier chains within the automotive industry for instance.

Problems concerning Internet bandwidth and security aspects have not been taken into account in detail, since WebFlex-PDM focuses on the underlying technology, not on the infrastructure issues. But with the rapid development of VPN technology these issues will surely be solved since all commercial WWW services rely on security and performance.

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