IMPLEMENTED WEB SERVICES FOR DATA INTEGRATION IN A FEDERATIVE ENVIRONMENT

Prof. Dr.-Ing. Klaus Schützer, schuetzer@unimep.br
MSc. Eng. Antonio Álvaro de Assis Moura, atamoura@unimep.br
Methodist University of Piracicaba
Lab. for Computer Application in Design and Manufacturing (SCPM)
Rod. Luis Ometto (SP 306), Km 1
13451-900 Santa Barbara d'Oeste, SP
Brazil

Prof. Dr.-Ing. Reiner Anderl, anderl@dik.tu-darmstadt.de
Dipl.-Ing. Christian Mosch, mosch@dik.tu-darmstadt.de
Technische Universität Darmstadt
Department of Computer Integrated Design (DiK)
Petersenstraße 30
64287 Darmstadt
Germany

Abstract.

The manufacturing process has been developed along the last years to become a collaborative activity; this process is supported by computer aided systems (CAx). As a collaborative activity, yet still centralized in one production plant, the manufacturing process became a distributed process where each phase of the process can be executed by different companies or people. This evolution was possible thanks to the developments in information technology which supports the whole process management.

Due to short product life cycles, increasing variety of products and short cycles of leap innovations manufacturing companies have to increase the flexibility of factory structures. Flexibility of factory structures is based on defined factory planning processes in which product, process and resource data of various partial domains have to be considered. Thus, now the factory planning processes can be characterized as iterative, interdisciplinary and participative processes.

To support interdisciplinary and participative character of planning processes, a federative factory data management (FFDM) as a holistic solution will be described. FFDM is already implemented in form of a prototype. The interim results of the development of FFDM will be shown in this paper. The principles are the extracting of product, process and resource data from documents of various partial domains providing as web services on a server. The described data can be requested by the factory planner by using a FFDM-browser.

***Keywords**: BRAGECRIM, Factory Data Management, Web Services, Manufacturing Process Planning*

1. INTRODUCTION

Today the product creation cycle can be considered as a collaborative and distributed process. Collaboration due to the stages of product or factory creation carried out by different actors who must work in a common way. As these actors are spread all over the world and also spread in relation to time - in this case considering the evolution of the development process in a time line - this process can be considered distributed. The complexity resulting from inherent characteristics in any distributed process can be managed by information systems. Within these information systems several requirements have to be improved. One of these improvements is the exchange of data among different systems within factory planning processes. As each one of the actors process uses its own solutions, developed to suit specific needs, which adds to the diversity process (Urbanic & ElMaraghy, 2006).

In development cycle of factories a set of activities developed in collaborative and distributed enterprises requires a flexible and adaptable factory planning process interrelated and independent of time and place. The concepts of concurrent engineering and agile manufacturing, according to Godinho Filho & Fernandes (2005) have to be considered in product creation as well as in factory creation and planning processes.

Complex and innovative products have to be available to the market in ever shorter time. IT-systems supporting planning and creation processes within the Product Creation Cycle are systems like PDM, CAD, CAM, CNC, ERP or BPM systems (Product Data Management, Computer Aided Design, Computer Aided Manufacturing, and Computer Numerical Control, Enterprise Resource Planning, Business Process Model). For those systems different modes of data management exist; data management systems and IT tools supporting factory creation and planning processes are rare and isolated solutions (Masson, 2006).

One approach to increase factory creation and planning processes is to integrate existing systems. Data can be stored in a single database, making information accessible to all necessary systems. Implementing this approach is a big challenge. With a view to product development, every phase of product development is implemented in an isolated way by experts in a highly distributed network. Results are distributed information on each system.

Knowledge of factory creation and planning process as well as manufacturing processes itself are spread across several experts in different organizations and domains in different localities. Goal is to involve and integrate different organizations, domains and experts in form of partial models into the factory creation and planning process. Thus factory creation and planning process can be described as a collaborative process like product development process. As a result of distribution each partner implements its own partial business process model (Teófilo & Silva, 2005).

The framework of information technology supporting these processes should reflect this distributed environment in such a way that ensures the right information at the right time for decision making, regardless of the actor who holds this information. Thomasma & Noller (2008) gives an example of working with data from various sources in various formats and manages these data autonomously by each application involved in the development cycle of technical systems like factories.

Due to the described challenges, a Federative Factory Data Management (FFDM) was developed. This FFDM is based on Service Oriented Architecture (SOA). The implementation of SOA is realized by using of Web Service technology and eXtensible Markup Language (XML). Within this paper the focus is on the description of the implementation of supporting distributive product, process and resource data based on Web Services. The Front-End interface in form of a FFDM-browser is not core of this paper.

2. *FEDMAN* – FEDERATIVE FACTORY DATA MANAGEMENT

The *FEDMAN* project, an acronym for "*Federative Factory Data Management based on Service Oriented Architecture and Semantic Description Model on XML and RDF for Manufacturing Products*", is a research project pertaining to the program BRAGECRIM (*Brazilian-German Collaborative Research Initiative on Manufacturing Technology*) funded by CAPES (Brazil), DFG (Germany), CNPq (Brazil) and FINEP (Brazil).

This research project proposes a layered structure to manage factory defining and representing data relating in a federative way with the use of Web Services. The project structure, presented in Figure 1, is composed of an

- **back-end-layer**, where services access data from specific applications by sing XML,
- an **intermediate federation layer** containing the Web Services and a
- **front-end layer** in form of a browser aggregating distributive data from multiple isolated applications. The front-end-layer is not focus of this paper and was already described in detail in Mosch et al., (2011).

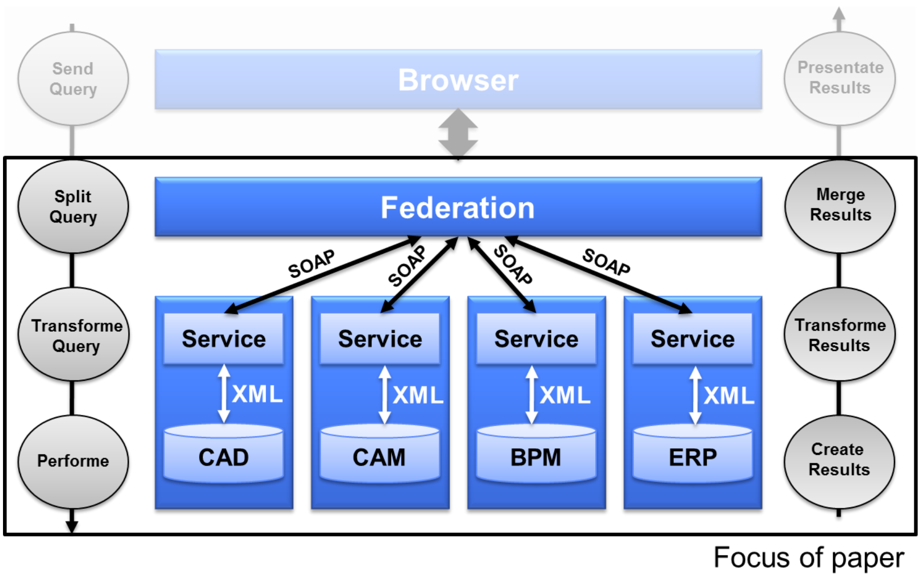

Figure 1. *FEDMAN* Structure

The **back-end** and **interface** layer are responsible for data on the collaborative process of manufacturer that are locally generated by the isolated and distributed applications used in each step of the factory planning process. Individual applications are responsible for creating and maintaining the data needed for this phase. Data made available by local applications are stored on the web and can be accessed by Web Services created specifically for this purpose. Web Services meet a request by a client using the FFDM (Federative Factory Data Management) -browser in form of a SOAP (Single Object Access Protocol) message distributed by the federation layer. At this request, the Web Service collects the necessary data and sends a response to the browser.

The **intermediate federation layer** adds a browser and federative distribution of information allowing the factory planner to manage following data:

- Process data resulting from IT tools like CAM and BPM systems,
- Product data resulting from IT tools like CAD systems and
- Resource data resulting from IT tools like ERP and BPM systems.

The flow of information proposed by the *FEDMAN* project will be initiated by a factory planner using a FFDM-browser (front-end-layer). The factory planner requests data for planning of manufacturing activity. This request involves the federation layer that makes the choice of appropriate Web Services and forwards the request. This intermediate federation layer has service access to data released by domain-specific autonomous applications in the back-end layer. The response of a request will be generated and sent to the front-end-layer (browser) that combines the results and presents these to the factory planner.

To get a platform supporting factory planning processes that are more flexible, able to adapt quickly to market needs, responding to pressures such as launching new products with quality assurance, the development of technology tools information capable of working with large volumes of data in a decentralized environment is imperative.

The data for factory planning processes resulting from multiple independent, isolated and autonomous tools and information technology are heterogeneous, since each application is free to generate and manage data. The integration of these data requires a conflict resolution and transformation of heterogeneous documents and data sources into an integrated concept (Lubell et al., 2004). Even though the data management systems for specific fields mature enough, the collaboration between these systems do not exhibit the same level of development. All domains involved in factory planning processes have to collaborate with the central model, this time the data integration problems arise and must be solved.

Within the concept of extended enterprise, factory planning processes do not only share data from applications which are involved directly, but also business information as it contemplates the supply chain and information from independent developers. The exchange of data in itself is a difficult problem to solve; sharing information is an even greater challenge. According to Abbas (2008) sharing information for the manufacture depends on the following aspects: semantics, standards, globalization and people.

3. SCIENTIFIC CONCEPT

The consideration of the complexity of factory planning processes, as related to the large volume of data or to the heterogeneity of these data are pertinent. However, only the data volume or diversity are not sufficient to characterize the complexity in its strictest sense.

This paper demonstrates the possibility of planning and managing manufacturing systems by reducing the problem to known solutions and using IT- technology to handle the large amount of data. In general, manufacturing system can be described by three basic elements: Product, process and resource. Each of these elements is divided into units, where each Web Service is an agent responding a request. The large volume of data from these Web Services is managed in the intermediate federative layer that forwards requests to Web Services and receives the response from them. Thus the planning and management of manufacturing systems, besides complex, can be done through a federated approach.

3.1. Processes

Various definitions of process exist in literature. The term “process” is applied to various fields of knowledge. In the field of production the definition of process is described as an activity that receives an input, adds some value and generates an output (Bandara et al., 2007). Especially in production the idea of activity that moves toward the final product can be defined as a hierarchy of processes as proposed by Giugliani & Varvakis (2007).

According to Hans-Erik & Penker (2000) a business process model (BPM) is a simplified view of the business, which allows a better understanding of the business and works as a plan for its management. A BPM does not predict all the responses necessary to conduct the business, but limits the search for solutions and presents a basic strategy to follow. In this sense a BPM should reflect the organization's process that is performed by specific people or by automated systems. Organizations are complex systems involving people and equipment. Thus building up a BPM is necessary to include the organizational structure and their links to a precise description of the actions being considered (Dumas, van Der Aalst, & H. M. ter Hofstede, 2005).

The manufacturing view is, necessarily, constructed by a process model done through modeling techniques that describes (usually in a graphic view) the activities involved in the process. The workflow can be added to the organization database to enhance the functionality including metrics that can be used to evaluate the process efficiency. (Bandara et al., 2007).

Within the *FEDMAN* Project manufacturing processes are described by a BPM. The chosen BPM language is Event-driven Process Chain (EPC) by Scheer (1996). The chosen process is a real manufacturing process within the process learning factory CiP (Center for Industrial Productivity) at Darmstadt University of Technology. Manufacturing processes described in EPC are typical processes on factory level. Processes on machine level like operations in tooling machines are also processes resulting from CAM systems, which have to be considered and are implemented.

3.2. Resources

Manufacturing resources are distributed in a multitude of agents, each with different sources and capacity. These agents play an important role and the same variable within the manufacturing system, the proper management of these resources is essential for managing the system as a whole.

According to Chengying (2003) a model of manufacturing resource information must have at least the following characteristics: Flexibility, Consistency, Integrity and Availability. This author proposes an information model which has three-dimensional architecture in the axis of the organization. In contrast, (Yuan, Nian, W. & Sun, 2008) proposes an information model for managing the manufacture composed by isolated models in which, the model for the resources contains the definitions for the human and technological resources that are involved or available to perform a task. Links with other models that comprise the central model of manufacturing management is done dynamically for each activity.

The evolution of MRP II (Material Resource Planning) systems began with the incorporation of some features like the possibility of more complex calculations and use of information from other systems. At this point of development where integration has become a key word, there was a new step and a new name for the systems that manage the resources not only manufacturing, but all (or at least intend to) business resources. This new system is known by the acronym ERP (Enterprise Resource Planning) and incorporates financials, costs, sales, human resources, and still others, previously managed by isolated systems (Hypolito & Pamplona, 1999).The integrated enterprise management system provides inputs to the processes defined in the business model will achieve the corporate goal.

Within the *FEDMAN* project resources are also a result of BPM and CAM system. Within BPM resources like machine tools are defined on factory level. Resources on machine level are manufacturing equipment like tools.

3.3. Products

The product view can be reduced to the product itself. As defined by Kotler (2003) products are anything offered to the market to use, purchase or consumption with the possibility of attempting a need or desire. Products can be expanded to meet to a bigger scope than just the physical object as defined by McCarthy (1976), including accessories, installations, usage instructions, packaging, name, relationship with some psychological needs, and the certainty that will be available technical assistance necessary to keep the consumer's needs are met after purchase.

For the product model Krause et al. (1993) distinguished different types, which allow a (even incomplete) deeper view on the subject. The proposed types are:

- Models of product oriented structure;
- Models of the geometry oriented products;
- Models based on product features;
- Models based on product knowledge;
- Models of integrated product.

Other models may also be considered, such as models based on materials, or kinematic models with very specific fields of use (Nielsen, 2003).

For managing the lifecycle of products PLM systems (Product Lifecycle Management) were developed and designed to manage both the issues related to engineering and the development of products. According to Brandão & Wynn (2008), PLM is "a business strategy approach that applies a set of business solutions in support of collaborative creation, management, dissemination and use of product definition information across the enterprise, the design to end the cycle of life - integrating people, processes, systems and business information." The PLM system is primarily an extension of the PDM system, which comes from the English acronym PDM (Product Data Management), which in turn operates predominantly in the areas of product engineering and encompasses a portion of the product planning and process engineering. Current PLM systems operate from product planning to its maintenance, repair and disposal, involving suppliers and customers (Eigner & Stelzer, 2009). Therefore it is possible to say that PDM is still the base of the PLM (Brandão & Wynn, 2008).

Within *FEDMAN* project product can be a result of PDM systems as well as from CAD systems directly. The chosen product is a pneumatic cylinder used in CiP at Darmstadt University of Technology.

4. IMPLEMENTATION OF THE CONCEPT BASED ON SOA AND WEB SERVICES

The scenario of distributed factory planning processes can be understood as a complex scenario, especially when taking into account that for each type or level of production several systems or applications exist and have their own characteristics. The factory planning process in its broadest conception also considers factors across external factors that act by increasing number of interactions and also variety of information included in the process, while requiring a coordinated performance from the systems that manage this information (Schwarzenbach & Wagner, 2005). Another issue is the consideration of legacy systems, since historically the development of products or factory structures work with standalone systems that are often chosen for non-strategic and operational criteria (Masson, 2006). These legacy systems must be incorporated into the management system of factory data so that this information is aggregated at the core model. Besides these factors, the presence of more than one factory in the same scene, operating a different system of software, only increases this complexity (Masson, 2006).

The management of distributed data in a collaborative manner can be realized in three different ways according to the work of Abeln (1997), Montau (1995) and Pedersen (2005), as presented in Figure 2.

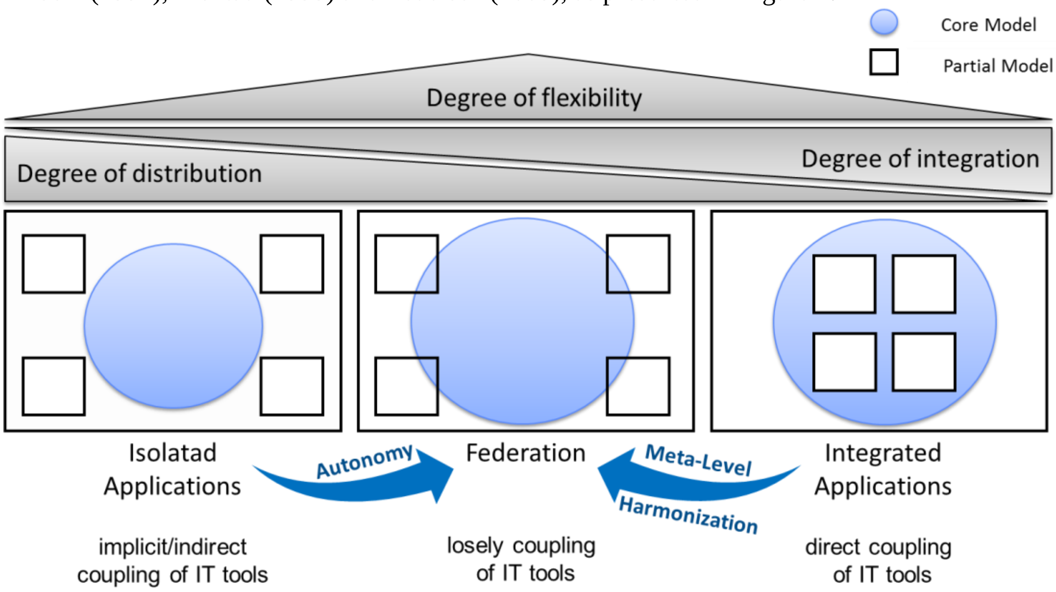

Figure 2. Management of Distributed Data in three different ways. Abeln (1997), Montau (1995) & Pedersen (2005).

The maintenance of data in **isolated applications** ensures a high degree of distribution, and preserves the autonomy of data that can be handled independently by each application. Each isolated application makes an indirect coupling with the core model of a factory. This described possibility of data-management has minor flexibility and low degree of integration due to the implicit coupling between the tools of information technology to comprise the core model. One difficulty with isolated data management is the way to deal with the data of coupled systems, which require a specific application for each entry to the central model.

Another option is the choice of fully **integrated applications**, where data of partial models are integrated into the core model. Creating a database model is a monolithic data distribution, since all applications are integrated and the connection to the core model occurs through direct links. In contrast to the previous model, this possibility of data management does not show a high degree of flexibility due to the fact that every change in a partial application or model impacts changes within the core model. On the one hand the high degree of interaction allows full system control; on the other hand a loss of autonomy exists as a result of the missing responsibility of applications for generating or manipulating data at partial models.

The intermediate solution between the two possibilities of data management presented is to allow data to be distributed in isolated applications, but the construction of the core model is realized by means of loosely coupling of IT tools - **federation**. Thus, the characteristic of autonomy for the management of data for each application remains at the same time that the core model is harmonic. This intermediate solution maintains the independence of each application and makes each piece work with the whole within their specific ability (Schwarzenbach & Wagner, 2005).

A solution for managing data in a heterogeneous environment must maintain the autonomy of distributed applications in order to ensure autonomy, while integrating data from various applications. The use of a SOA enables the migration of a monolithic system to a distributed system, as the central model is built through a layer of services which they operate individual applications.

4.1. Service Oriented Architecture

According to Josuttis (2007), SOA is an architectural paradigm that deals with business processes in distributed heterogeneous systems, facilitates the interaction between service providers and consumers of services, enabling to locate and utilize the capabilities of distributed they need, even if they are under control of different owners.

SOA considers functionality in layers, where the existing or legacy systems that effectively deal with the data, give the foundation of architecture, these systems are providing data to build the core model. The top layer consists of a layer where the security, transportation and mediation between the services is, may also be in this layer business metrics, and processes. The top layer contains the processes that consume the services.

In SOA a middle layer exists (see Figure 3) which makes the links between services and applications; communication between services is done through exchange of messages using the SOAP protocol and usually XML. The services accessing the data and isolated applications comprise the central model, thus the data needed for product engineering, are not replicated in each model, but rather aggregates of federative way.

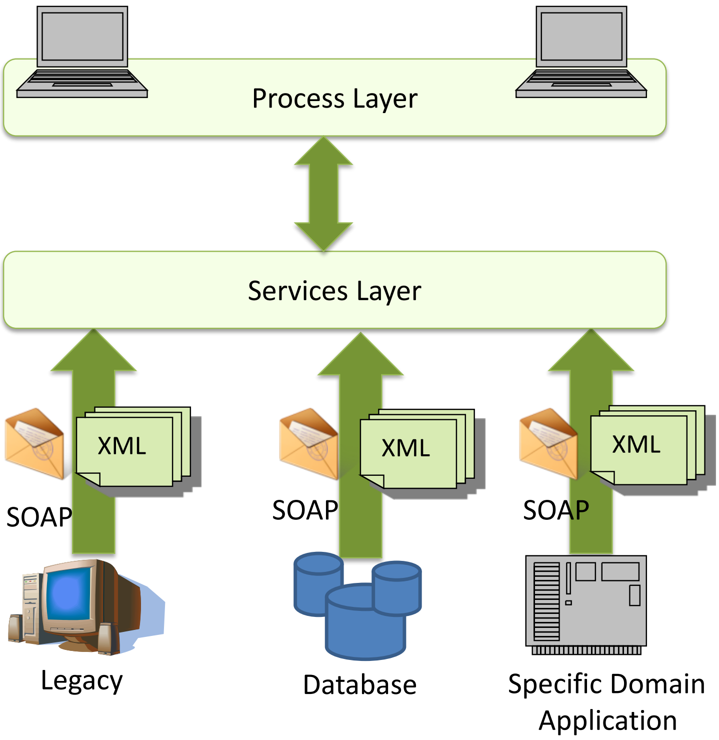

Figure 3. SOA schema

According to Booth (2004), Web Services are defined as a software agent that enables the machine to machine interaction over a network and has an interface described in a format that can be automatically interpreted, specifically WSDL (Web Service Description Language). Other systems may interact with a Web Service through SOAP messages. Typically is the use of HTTP (Hypertext Transfer Protocol) data in XML (eXtensible Markup Language) in conjunction with other related standards.

In a concrete view, the implementation of a web service is done through exchange of messages between a service provider and a service requester. These messages can range from simple data to complex objects. A requester is an entity that wishes to make use of functionality provided by the service provider to do this send a message to another agent and receives a response message. Message as it is understood from a specific data to a complex object.

For this both, requester and provider, must first agree on the semantics and the mechanism of exchanging messages, establishing an agreement made based on the description of the service that determines the format of the message, type data communication protocols and serialization mechanisms, is also established in the local network where the service is available. In describing the service the location of the network service, which can be accessed, is established.

Within the context of a Web Service, semantics understands the expectations about the behavior of the service, particularly in response to messages sent. For an isolated Web Service semantics is not so important, but in a SOA for a distributed system, the semantics of Web Service is essential to the adequacy of the application of the correct response. While the service description represents a contract between the parties, the semantics represents a contract governing the meaning and purpose of enabling the automation of service use.

In general the use of a Web Service is shown in Figure 4 mode by following the steps, which may or may not be automated:

1. the requester and provider known each other;
2. the requester and provider agree on the semantics that will support interaction;
3. the service description and semantics are performed;
4. requester and provider agents exchange messages by sending requests, processing them and getting answers.

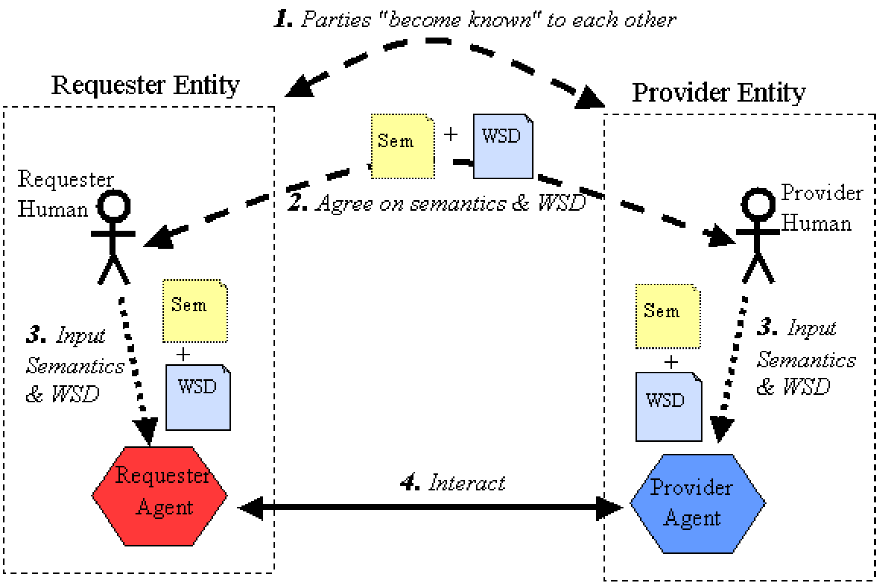

Figure 4. Web Service general process (Booth, 2004)

Referring to Figure **1** the implementation of the particular layer based on Web Services will be described.

4.2 Back-End-Layer: Applications Layer and Service-Layer

The lowest level of the SOA proposed in Figure 1 consists of the applications used in product development, production planning and production controlling within each specific area In detail contributing the development of products CAD system, for the definition of processes BPM tools or CAM systems and for the management of resources ERP systems are used. These systems are distributed and autonomous and are responsible for managing data. Each of these systems provides the means to deliver the necessary data for global management proposed by the project. For developing the FFDM prototype, applications have been created for product, processes and resources data.

- Product Application
  An internal application within a commercial CAD–system was developed, which reads requested data based on product data, creates a file in neutral document (like ISO 10303-214 STEP, in accordance with Part 28, or XML) and export the requested data into this neutral document.
- Processes Application
  In *FEDMAN* an internal application within a commercial CAM-system was developed for the description of manufacturing processes/operations. In the same way as for the CAD-system, this application reads the machining processes and provides these data within a XML-document. Thus these data can be extended to encompass a larger amount of information.
- Resources Application
  The factory structure of CiP at Darmstadt University of Technology was described in an EPC-model and these data provided in XML-documents containing the available resources like tooling machines as well as its operational capabilities. The human resources were also considered within the BPM.

In the service layer are located the agents responsible for collecting the information provided by applications and to forward this information to the federation layer.

For each of the applications within the *FEDMAN* project has developed a service that corresponds to each of the views of the manufacturing system. To maintain the standard in the *FEDMAN* Project and to use the most recommended current technologies, all the message exchange among Web Services was made using XML. The Web Services are:

- Web Service for the Product
  This service collects product data, as provided by the CAD-system, and returns the response requested by the federation layer. The possibilities are requests for information regarding the current parts that belongs to an assembly and about these parts can be requested: the location, material, type, quantity and owning part. Although is developed just a prototype, it already provide services that supports to retrieve information from a product version.
- Web Service for Process
  Data about processes are collected by a Web Service in the database created by the application inserted into the

CAM system. Each operation generated by the CAM system is associated to a operation type and used tool. These are the information that can be retrieved by the planner using the Web Service.

- Web Service for Resource
  The Web Service reads the data from the XML document resulting from a BPM and returns the information requested by the federative layer.

At the current stage of FFDM development it is possible to obtain the information available for a particular machine and its functions as well as the human resources related.

4.3 Intermediate Federation Layer and Front-End-Layer (Browser)

The two upper layers, federative and browser, works together, giving the planner an overview of factory planning processes.

The browser presents a user-friendly interface in which the planner can visualize the relationships between: Products and Resources, Product and Processes, and Resources and Processes.

For each of these views the federative layer requests the relevant information services and the browser allows the planner linking between views. A detail description is done in Mosch et al., (2011).

5. CONCLUSION AND FURTHER WORK

This prototype reached the *FEDMAN* goals, showing a way to work in a federative database for a manufacturing product. Data on processes, resources and product are stored in different locations and can be accessed through the web, without restriction of location. This feature demonstrates the collaborative and distributed product development.

The solutions presented for the systems that generates the information required for manufacturing system (CAD, CAM, ERP or BPM) are the same. This demonstrates the ability to reuse solutions and also the integration of legacy systems to the central model.

Although just a first prototype was implemented, all features required in the project scope are available.

Within the *FEDMAN* project is planned to include systems for data security in transactions to ensure the integrity of the rights on the information.

Another module is on development for the creation of a virtual environment in which will be possible to test solutions proposed in this project.

6. ACKNOWLEDGEMENTS

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