MAPPER Collaboration Platform for Knowledge-Intensive Engineering Processes

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Abstract. The paper presents a collaboration platform with model-based configurable services. It is a part of a more general approach developed by the EU project MAPPER that enables distributed collaboration over adaptive knowledge-intensive engineering processes. In a model-configured infrastructure, active knowledge models (AKMs) of products and processes become the basis for user-composed services, tools and methodologies available to users in customisable workplaces. A multi-layered architecture that offers a powerful means for configuration of services for particular application areas has been described. The presented approach and the collaboration platform have been experimented with in a collaborative engineering use case in electronic industry that integrated two dispersed SMEs. Experiences learned are summarized.

Keywords: enterprise modeling, collaboration platform, distributed collaborative engineering, task patterns.

1 Introduction

More and more complex products are being produced these days, like new mobile phones or vehicles. Engineering processes involved in design and manufacturing of such products are sophisticated, heterogeneous, and very often distributed among dispersed enterprises. Difficulties are consequences of essentially different design techniques required for designing heterogeneous components, being: software, digital or analogue hardware, optical, mechanical or even biological components, as well as in their integration and verification. Designing and integrating such diverse components require collaboration of expert designers that often are available in remote locations only.

In such knowledge intensive industries, like automobile and electronic ones, design and manufacturing processes are heavily based on design and product reuse. Electronic industry demonstrates additionally, new management and control of demand-supply chain with global collaborative networks of involved enterprises [12], [13]. This enables the partner companies to compete against others in terms of time to market, product flexibility and shared knowledge. Information flow in enterprise networks, as

well as enhancing design processes through effect reuse of engineering knowledge are definitely important aspects of this agile engineering style.

Enterprises in response to global market challenges re-engineer their business models, services and internal structures. The ability to quickly adapt to changing market needs and to cooperate flexibly has become a key element for maintaining competitiveness. This is reflected in the increasing importance of concepts and technologies that support distributed collaboration of enterprises. Industries are moving towards networked organisations, such as collaborative networks and dynamic business ecosystems. Products must be rapidly adapted to customer needs, leading to faster innovation cycles and more complex distributed collaborative engineering. In many industry sectors, a demand for increased value creation on the supplier and sub-suppliers side of the networks is observed, emphasising knowledge content and services. This requires significant growth in inter- and intra-enterprise knowledge reuse and sharing, management services and in new collaborative work environments.

Collaborative environments commonly support communication, collaboration and coordination aspects, which contributes to implementing information logistic principles. The research field of information logistics aims at optimizing information flow and providing demand-oriented information supply. Only the "right information" should be provided to a user engaged in a collaboration situation "just-in-time". Information logistic especially contributes to coordination support and improves awareness for changes within the distributed work group.

The paper presents the MAPPER project[1] knowledge model-based approach [7] that enables adaptive product and process engineering [8] and supports knowledge-intensive innovative design processes. The approach comprises active knowledge models [1], a collaboration platform, customisable workplaces, a participative engineering methodology and a set of practices defined as task patterns [14].

This article is organised as follows: the MAPPER approach is presented firstly, while the collaboration infrastructure and its components have been detailed in the following section. Main services of the infrastructure, namely: knowledge models, asynchronous and synchronous communication services, as well as secure invocation of remote tools are presented. Finally, the use case with distributed engineering has been addressed.

2   The MAPPER Approach

The main technologies of the MAPPER project are illustrated in the centre of Fig. 1. Configurable *active knowledge models* (AKMs) [1] [9] of products, processes and other enterprise aspects are used for configuring and coordinating both the human and technical aspects of collaborative design. *Customisable workplaces* give different stakeholders access to the information and services they need for performing their tasks. The *secure collaboration platform* enables enterprises to use each other's engineering tools and product data in a collaborative, yet secure manner, while *participative engineering methodologies* guide joint product and process design, interdisciplinary and inter-organisational collaboration throughout multiple product lifecycles. Each of these main components will be explained in the following sub-sections.

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[1] MAPPER - Model-based Adaptive Product and Process Engineering, FP6-2004-IST-NMP-2 Project No. 016527, 09.2005-02.2008, `http://mapper.eu.org`
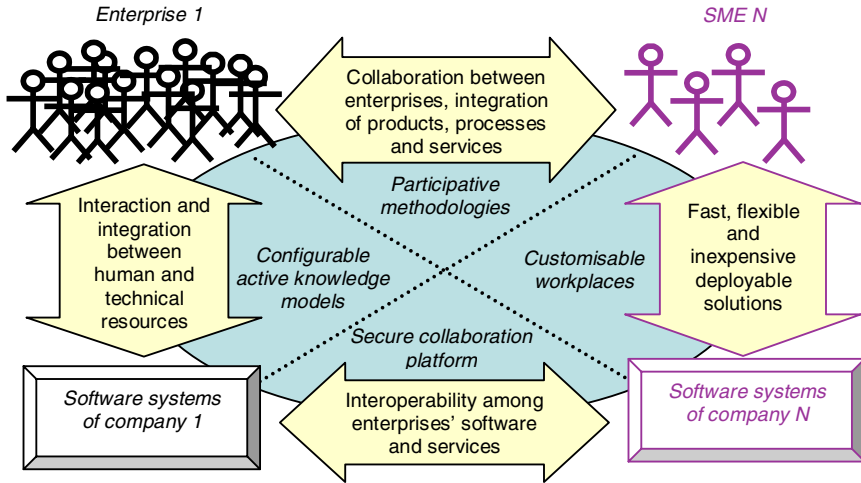
Fig. 1. Overview of the MAPPER approach

2.1 Configurable Active Knowledge Models

Through visual models that reflect evolving business knowledge, all the other elements can be configured and composed. The models are thus used *actively* to customise and adapt the IT infrastructure and the models are executed through process enactment and rule engines. Active knowledge models differ from conventional model-driven architectures (MDAs) in that they primarily capture user knowledge about business realities, rather than technical information about how the computerised support systems work. AKMs thus let evolving business needs directly control the IT infrastructure. Its interactive model execution paradigm [8] creates IT support for the innovative design processes at the core of the business' competitive advantage, not just for the administrative support processes.

Product design today typically involves a multitude of engineering and other disciplines, often from different companies and nationalities. When such a project is to use the MAPPER approach, methodologies and infrastructure, the first step is to build a *scaffolding* model for the project. This model should contain the information needed for setting up a *collaboration space* for the project on the Web, e.g.:

- *Product model:* What kind of product is to be designed, what are the constraints and requirements, which components should it use etc.?
- *Organisation model:* Which companies and people are involved in the project?
- *Process model:* which overall project work plan and general procedures should be followed?
- *System and infrastructure model*: which IT applications and services should be used in the project? Which are the overall content models for managing and navigating project information, etc.?

2.2   Customisable Workplaces

The collaboration platform supports model-configurable workplace components in order to provide each user with the services, information and communication channels needed for performing his or her tasks. These workplaces are available in two main formats:

- *Web workplaces,* easily accessible interfaces for performing well-defined tasks and conventional information processing, e.g. through forms and reports.
- *Visual workplaces,* displaying, organising, modifying and interacting with active knowledge models, defining and doing work at the same time, handling complex and poorly understood problems in innovative ways.

2.3   Collaboration Platform of Model-Configured Services

An ICT infrastructure for model-configured, user-composed services has been developed in MAPPER. These services span different layers:

- *Infrastructure services*, accessible through application programming interfaces, as socket-based communication services (Web services, with explicit XML interfaces and interface definitions (WSDL), accessible over SOAP.
- *User services*, such as interactive portal services and portlets, accessible e.g. as URLs with parameters, pluggable inside HTML frames. Tools and applications, consisting of a number of related software functions, are often used by a specific role to perform a job.
- *Business services*, that are offered, sold and delivered by a company, like products, including generic services (ERP, PLM, application service provisioning etc.), industry sector specific services (e.g. chip design) and company specific services.

The IT industry delivers services across all of these layers. Enabled by a model-configured infrastructure, higher level user and business services can be more easily adapted and composed.

On top of the infrastructure layers, more complex functionality can be model-configured for individuals, groups, projects, companies, business networks and communities. In particular, generic solutions for methodologies were operationalised by configuring lower level user and infrastructure services into coherent task patterns. Each layer filters, combines and contextualises services from the layers below to construct increasingly customized services for business users. In the service teams that perform this customisation, ordinary users and super users are supported by experts on solution and platform modelling. The platforms can thus be extended on different levels.

The system and infrastructure model represents the Web services offered by the components of the MAPPER infrastructure, or by other systems used in each company.

2.4   Participative Engineering Methodology

The objective of the *participative engineering methodology* is to facilitate participative engineering in a networked manufacturing enterprise. The knowledge

modeling approach has been used for the development of a methodology consisting of reconfigurable and customizable models. Interdependent sub methodologies are integrated in the overall methodology knowledge model to support the following challenges:

- *Collaboration among humans in a networked enterprise:* How should we go about forming and retaining fruitful collaboration relationships with other people, inside and outside a company?
- *Organisational learning in a networked enterprise:* How should we provide for maximum learning in a networked enterprise? This also involves learning across organisational borders.
- *Multi-project portfolio management:* How to coordinate several parallel projects, where each one may have participants and resources from several companies.
- *Modelling a networked enterprise:* How to plan and perform a modelling effort, covering the whole life-cycle of models, from planning and development to application and management.

3   The Collaboration Infrastructure

3.1   Overview of the MAPPER Infrastructure

The modelling tool Metis [4] which provides services for capturing both the users' data and the configuration models that customise how the users' data should be interpreted constitutes the core of the infrastructure. The Metis Enterprise repository is used for storing the models, and the Configurable Web Portal consists of a set of model-configured components integrated with the Metis Enterprise portal. The visual front-end of the Metis client has been extended with information and view management and task execution to create *configurable visual workplaces* for various design roles involved.

From a group interaction perspective, one can classify the needs for group interaction in distributed virtual enterprises according to the dimension of time. *Synchronous support* is mainly required in the context of virtual meetings. The team needs communication facilities and means for interacting on shared material such as design documents or source files that make up the final product. In MAPPER, this kind of interaction is supported by the Concert Chat system developed at Fraunhofer IPSI.

Asynchronous interaction support is needed to help the team between the different design meetings. It requires that team members are able to share and modify material, discuss and coordinate issues that come up during the design task and stay aware of other users' activities that take place in parallel to the own activities. The CURE platform developed at the Fern Universität in Hagen supports such kinds of interaction.

In both contexts, the users need to have access to the required domain-oriented tools such as simulators or compilers. The tools may in addition require special facilities such as chip test beds or even larger physical installations, like a wind tunnel in the case of car manufacturing. The TRMS system developed at the Silesian University of Technology offers means for securely invoking domain-specific tools. The Tool Registration and Management System [10] enables distance-spanning tool
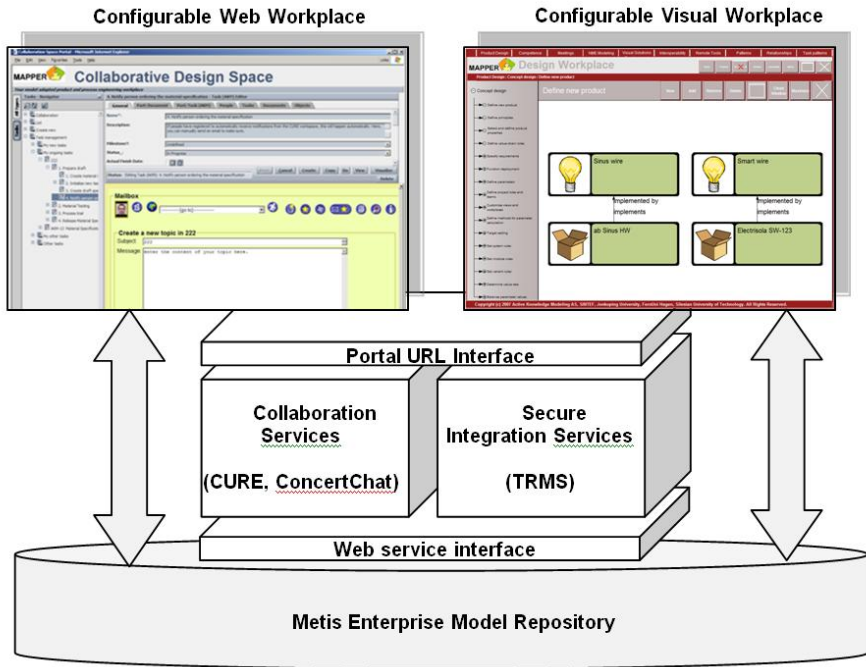
Fig. 2. Overview of the MAPPER infrastructure

integration. Once registered, tools provide their service for distributed design teams. The goal of this component is to allow designers to use tools that are installed at remote sites. All the above tools need to be combined to support task patterns for collaborative engineering. On a technical level, the task patterns are mapped to Metis models that represent the plan for the concrete interaction. Basically, the Metis model configures the user-defined portal. In the portal, the users find their tasks and related tools. The tools are configured by the AKM platform model enactment service that uses the tools' Web service interfaces. If the task requires, e.g., the creation of a set of pages in CURE, the AKM platform will create the pages using Web services. Additionally, a discussion space at the Concert Chat server can be established. Finally, if the task requires the execution of a design tool, the AKM platform will set up a tool configuration in TRMS and trigger the tool execution.

3.2 The Architecture and Its Components

The architecture of the MAPPER collaboration platform is organised as loosely interacting web services, thus the individual components stay as independent as possible while still allowing the users to experience a coherent usage experience. A diagram of the architecture is shown in Fig. 3, the details are explained below. The most important part is the Metis Enterprise Portal that provides the model enactment engine. This engine remote-controls the configuration of the other collaboration support tools. It reads an input from a METIS model describing the workflow

between different participants. The METIS model also includes information on the required documents and the expected results of each step in the modelled organization's processes.
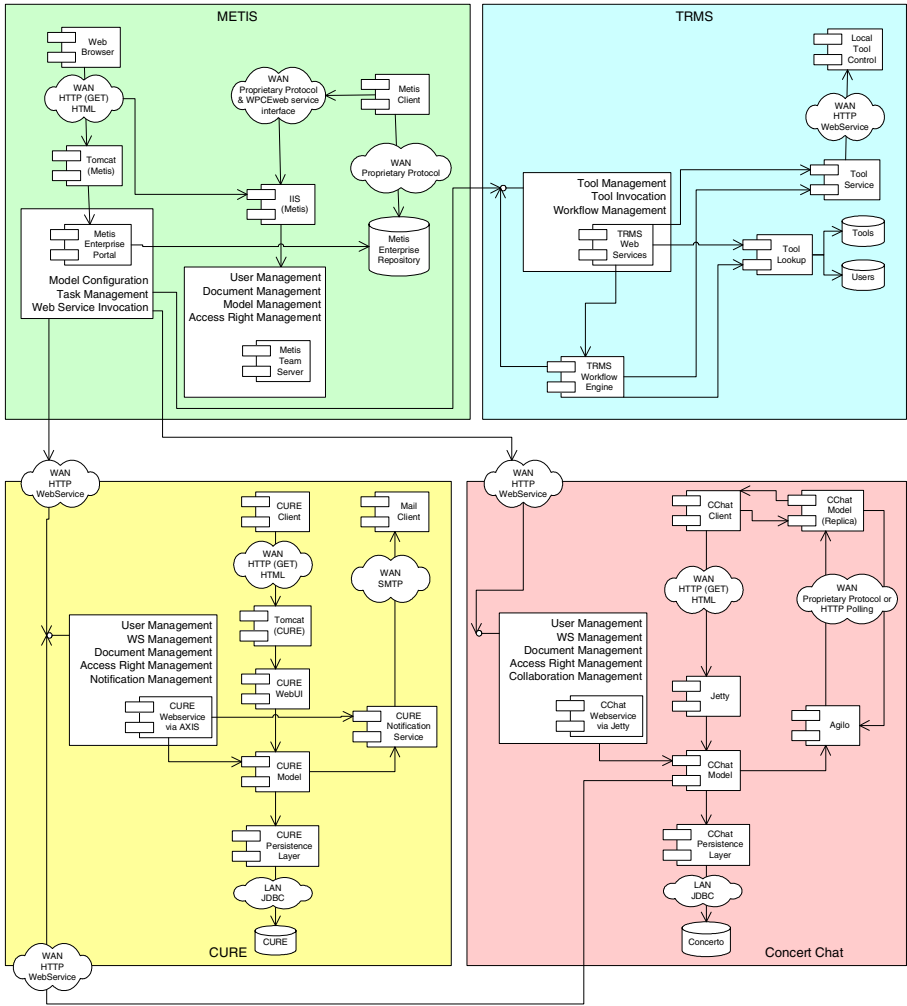

Fig. 3. The architecture of the MAPPER collaboration platform

At each step, the workflow engine detects the required tools, the interacting users, and the input documents. Based on this information, the workflow engine can configure the tools in order to create a collaboration environment that is tailored to the current step and provide this environment to the interacting users. In steps where collaboration support is required, the Workflow Engine will configure TRMS (for secure tool invocation), CURE (for asynchronous interaction), Concert Chat (for synchronous discussions), and other services referred to in the model. The configuration is achieved

by submitting a set of web service requests. Below, the components of the platform are shortly explained.

Knowledge modelling tool – METIS [4]. It comprises three main components:

- the *Metis Enterprise* (ME) platform which provides data collection, management, and delivery services required to build any enterprise modelling application,
- *Metis Team* is a file repository used for storing Metis models (views and data) as files. It may also be used for document management. In addition to the web interface used in the MAPPER project portal, Team content can be accessed and managed directly through the repository browser of Metis modelling clients.
- *Metis Client* brings advanced visualization, modelling and analysis to commercial enterprise and government users. This tool enables organizations to support the needs of additional users to enhance their existing Enterprise Architecture (EA) activities.

Remote tool invocation – TRMS [5]. Tool Registration and Management Services system [10] enables distance-spanning tool integration. The architecture (Fig. 4) of TRMS system comprises three main components: the Global Tool Look-up Services (GTLS) server with data bases, the Tool Servers and the Client application.
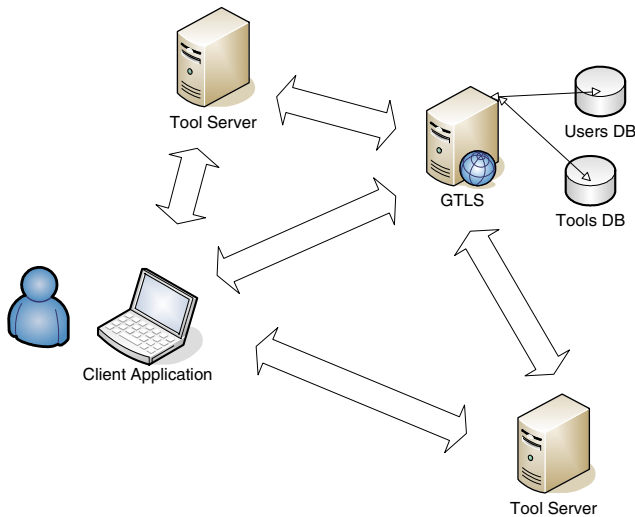

Fig. 4. The TRMS architecture overview

In a general case, all three TRMS system components run on separate machines connected to the Internet. All sensitive data are encrypted (ciphered) and digitally signed by a sender. The Client applet has a simple GUI that allows for login to the system, its administration and usage of available tools. The sequence of tasks to be performed is represented visually in the TRMS Client as a simple workflow. This workflow can be executed by the TRMS Client.

The Tool Server (TS) is responsible for controlling users' access to tools and their execution. A Client invoking a tool does it through the Tool Server. Its additional task

constitutes of brokerage in user authentication. The Tool Server queries GTLS whether a user who invokes a tool has sufficient privileges.

Collaboration workspace – CURE [2]. CURE is a web-based system that facilitates collaboration over the Internet using standard browsers [6]. From a user's perspective, CURE is based on a *room* metaphor combined with WIKI ideas, and communication tools. To use CURE, users need a CURE client, which can be any browser that is capable of JavaScript.

To build up structured collaboration environments, a room may be connected to adjacent rooms, thus forming a virtual collaboration infrastructure. Every collaboration infrastructure is represented by a designated entry room and all rooms recursively connected to it. In fact, a whole virtual organization can be constructed by creating an entry room of the network of partners, which links to collaboration spaces for each participating partner and teams formed by representatives of the partners.

Fig. 5. Asynchronous communication of engineers in CURE

A room contains pages, resources and communication tools, which are created, manipulated, navigated and read by users of the room. Users can add/remove/view resources associated with the room. Each room may have its own mailbox that is kept persistent. All users in a room can view and send mails through the room's mailbox.

Distributed engineers may communicate on the design documentation that is shared among design team members over the CURE room, as demonstrated in Fig. 5.

Concert Chat [3]. It provides synchronous collaboration services to the users by offering user awareness, text-based synchronous communication, a shared whiteboard, and referencing functionality using a virtual room to realize a shared workspace.

On the left side in Fig. 6, the shared whiteboard is shown. It provides a *content space* that can be used to share material among all collaborating users providing a spatial layout. The content can be obtained from asynchronous rooms in CURE. This way, Concert Chat adds synchronous interaction services to the set of asynchronous services of CURE. The top right of the figure shows the users that are currently participating in this session. Below is the *interaction space* that offers text-based

communication. In order to be able to directly refer to a shared material; chat messages can refer to regions of the shared whiteboard, but also to previous messages.

The Concert Chat server can be configured by the Metis Enterprise model enactment engine to set up collaboration structures for the tasks defined in the project model.
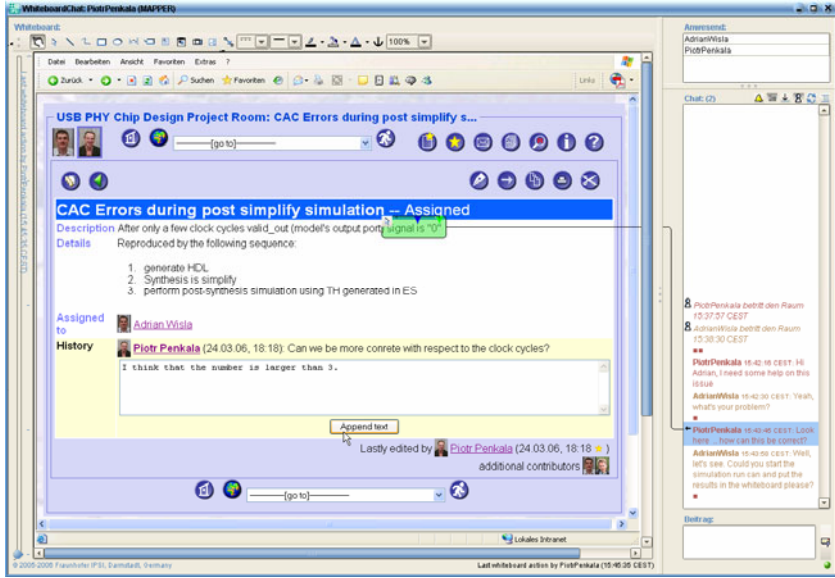

Fig. 6. Synchronous collaboration services provided by Concert Chat

4   Use of Active Knowledge Modelling in Engineering

Active knowledge models (AKMs) can be used *actively* to customize and adapt the IT infrastructure, and the models are executed through process enactment and rule engines. They can serve as systematically updateable knowledge base on the design environment with: relevant design processes including those used for quality assurance, required human resources, and tools. This can simplify transfer of design knowledge around a particular design phase or design task to new employees. AKM defined as a design workflow, when executed can support (semi-) automation of design processes;

AKMs in a natural way can model *electronic products* at various levels of abstraction, from simple Intellectual Property components to complex heterogeneous systems. Configurability of active knowledge models supports design of product families.

4.1   Use of AKMs to Collaborative Design of IP Components

AKMs have been deployed to collaborative design of an IP (Intellectual Property) component in the frame of the MAPPER project in an experiment that integrates two IP components development companies from Germany and Poland that aim at designing an advanced USB IP component. An IP component is required for

hardware implementation of standard serial communication protocols. Obviously, this design needs to fulfil constraints on "time to market", security of design data, and the customer-specific final product functionality. This IP design is being performed in a truly distributed collaborative engineering network that is being built upon the MAPPER infrastructure. Each node in this network constitutes an engineer's workspace equipped with design tools or just a remote tool that processes automatically design data.
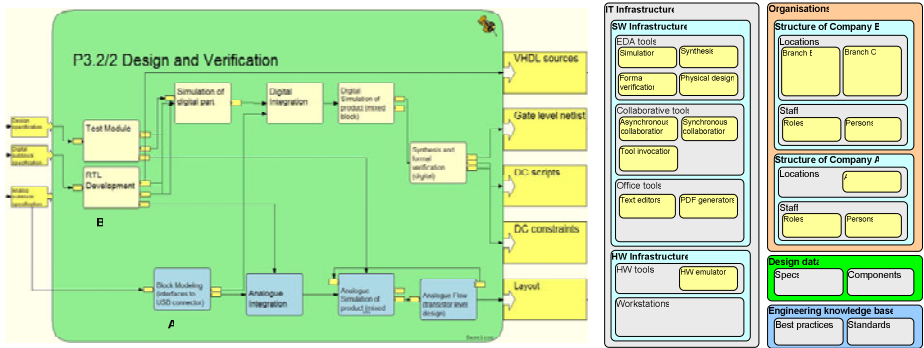

Fig. 7. A part of an IP component design represented as a visual active knowledge model

The presented model comprises a wide spectrum of information related to the current joint product, namely information on: the internal organizations of both involved companies A and E (e.g., a company structure, geographical locations, human resources, competence skills of staff), the available IT infrastructure (e.g., design automation, administration, and office tools), the current project organization (e.g., project responsibilities), the detailed structure of the joint product, and the project plan (e.g., management and design workflows). The model can comprise a large amount of elements, i.e., objects and relations, not easy to grasp, therefore there is a need for information scoping. It is possible to control visibility of model elements by creating different views with selected model components only. More details on this distributed collaborative engineering IP component design can be found in [11].

5   Conclusions and Further Work

A collaboration platform of model-configured services has been introduced in the paper. The multi-layered MAPPER architecture of services offers a powerful means for configuration of services for particular application areas. Experiments conducted in the use cases in automotive and electronics design domains prove utility of the presented approach and the platform for collaborative knowledge-intensive engineering processes conducted in dispersed groups. Selected conclusions from these experiments are enumerated below:

- Integration into one homogeneous knowledge model of various aspects of business processes, design processes, workflows, design environments with human and tool resources, is an important step towards knowledge-based engineering;

- Visual AKM representation of design processes, workflows and task patterns is natural to designers. Still work needs to be invested in elaboration of more electronic engineer specific profiles and views at the METIS web portal;
- Asynchronous communication and collaboration services provided by CURE were well adopted by engineers in their design flows.

Deployments of the presented collaborative infrastructure and the profound validation process resulted also in refined and new requirements for enhanced versions of the infrastructure, services and tools. Further applications will focus on concrete business services supported by the enhanced participative engineering methodology. Information on additional experiments and lessons-learned is available on *mapper.eu.org*.

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