Distributed Design of Semiconductor IP Based on The Workflow Concept[1]

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Abstract. *The concept of a workflow which enables automation of heterogeneous working procedures with distributed activities and data has gained popularity in recent years, predominantly in a business domain. Nowadays, workflows enter engineering communities, and they are quickly becoming a promising instrument for assisting an engineer in collaborative, site spanning design processes. In this paper, we discuss workflows from an electronic engineer's perspective. A modern workflow technology is demonstrated as applied to a distributed design process of a semiconductor IP. After briefing the IP design methodology currently applied at ITE, we present an ASTAI®-based workflow that has been developed for the purpose of task integration in a pan-European collaborative project E-Colleg. The project and its status are finally shortly presented.*

1. Introduction

The rapid development of the Internet and Internet-based standards during the past years enables transmission and delivery of electronic data less expensively and more securely. It is expected that ongoing transition from static data sharing to real-time data sharing will move very fast in this decade. The new, emerging paradigm of work supports collaborative engineering between distributed teams in both intra-company projects and company-spanning ones. This immense progress however increases the need for effective remote tool services, which can be used to extend the area of collaboration.

Workflow is commonly conceived as a concept to accelerate heterogeneous working procedures, which consists of a set of activities that support a specific process. Workflow specifications include the actions to be performed, statements on control and data flow among these actions, agents allowed executing actions, and policies that describe the organisational environment. In an electronic engineering domain, a workflow allows a designer to create a virtual design environment that integrates tools and services [2-4, 7, 11] (e.g. compilers, simulators, logic and behavioural synthesis tools, physical design tools, test equipment, product data management systems and/or databases) that are distributed over different sites, platforms, and often enterprises. Distributed tools and services require a workflow management system that supports enterprise level integration dealing with many kinds of cross-domain issues.

The paper presents the workflow technology applied to a distributed design of a digital camera specialised for medical applications. Two dispersed partners, namely Thales Optronique (Paris) and ITE (Warsaw) are involved in the discussed distributed design. The team involved in the digital camera task will have to be dynamically modified during the course of the project. Since team members will stay in remote locations their intersections, as well as constant access to automatically updated, distributed project documentation are essential. All these distributed, collaborative design issues will have to be supported by the collaborative infrastructure. ASTAI® [2] is a workflow management system developed by C-Lab (SBS) that has been applied in the described experiment as an underlying prototype technology. The system enables collaborative working in multiple-site, multiple-platform environments. Moreover, it offers a convenient, easy to use, set of graphic tools for design and management of workflows.

The main characteristics of workflows that are new to electronic engineers are intentionally exposed in the following two sections. Then a methodology for IP design used at ITE is summarised. Further on, we build and explain the workflow that implements this methodology, as well as explain its role in a validation scenario that has been planed in the 5th FP project E-Colleg.

2. The Workflow Technology

The primary characteristics of a workflow is the automation of real world (business, design, etc.) processes that involve human and machine-based activities, particularly those involving interaction with IT applications and tools. A workflow technology provides procedural automation of processes by management of a sequence of work activities and the invocation of appropriate resources associated with various activity steps. Although the workflow concept has been applied mainly in general administration operations within the office and business environments, in recent years, it

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becomes a fast growing technology, which is increasingly being employed by industries due to its usability to many classes of applications. A *workflow* is defined with the various process activities used to manage it during process enactment by procedural rules and associated control data. A simple graphical view of a process, represented as parallel and/or serial set of activities that are connected in order to achieve a common goal is shown in Fig. 1 as an example.

A workflow is usually organised in an IT system with the aim to facilitate or automate real world processes. In this context, a workflow is customarily a suitable solution due to the fact that it provides decomposition of the procedure logic and its IT operational support, therefore enabling subsequent changes to be incorporated into the procedural rules defining the processes.

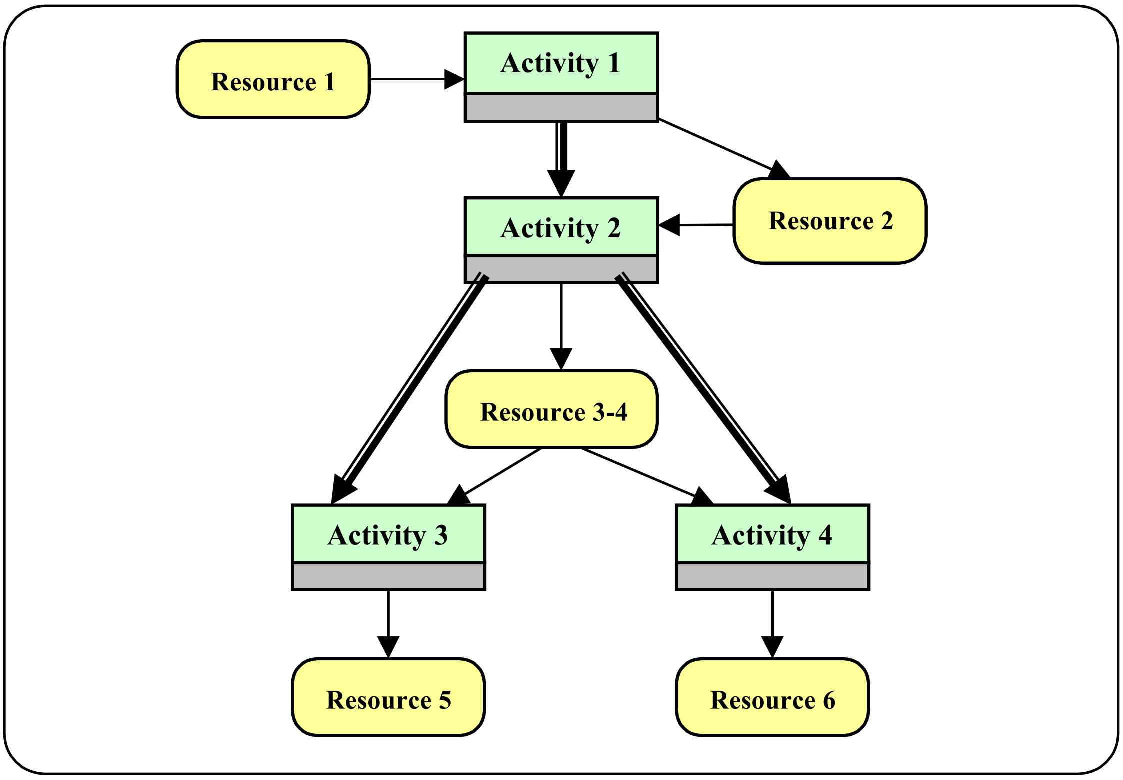

Fig. 1. A six activity process

Workflows are defined, managed and executed by a workflow management system through the execution of software driven by a computer representation of the workflow logic. Such systems may be implemented in many techniques, use different types of IT infrastructure and operate in a wide range of environments from small local to inter-enterprise workgroups.

Workflow management systems generally provide users with a possibility to define new workflow types, manage and execute workflows that have been defined and made available for setting up new working procedures. The term “workflow type” being used in this context refers to workflow classes and workflow instances, following object-oriented approach of presentation. A workflow contains *activities* and *data objects*. Both of them are understood as instances of activity and data object types creating a global type repository for the workflow design. Also, new definition of a workflow inherits from existing components of earlier workflow definitions.

A software service that provides the run time execution environment for a workflow instance is called a *workflow engine*. Workflow engines include a capability for an application tool invocation that is used to activate applications necessary to execute particular activities. The workflow engine mechanism may be implemented for simple systems that support a single fixed tool such as a document editor, or complex ones that provide methods for the invocation of a wider range of local and remote tools.

A workflow engine can control the execution of processes or sub-processes within a defined range determined by object types and their attributes, which it can interpret within the process definitions. Control operations within the workflow engine are based on workflow relevant data, that is the data generated or updated by workflow application programs, accessible to the workflow engine. The process definition, in conjunction with any run-time workflow relevant data is used to control the navigation through activity steps within the process.

Typically a workflow engine provides facilities to handle [11]:

- Interpretation of the process definition; control of process instances;
- Navigation between process activities; sign-on and sign-off of specific participants;
- Identification of work items for user attention and an interface to support user interactions;

- Maintenance of workflow control data and workflow relevant data, passing workflow relevant data to/from applications or users;
- Interface to invoke external applications and link any workflow relevant data;
- Supervisory actions for control, administration and audit purposes.

3. Workflow Reference Model

The Workflow Reference Model [11] describes the generic workflow application structure. It contains definitions of components and interfaces, which respond to real world applications and their interdependencies. This method allows creating of workflows, which fulfil requirements of many different implementations working on different levels of complexity including communication and data exchange between several applications.

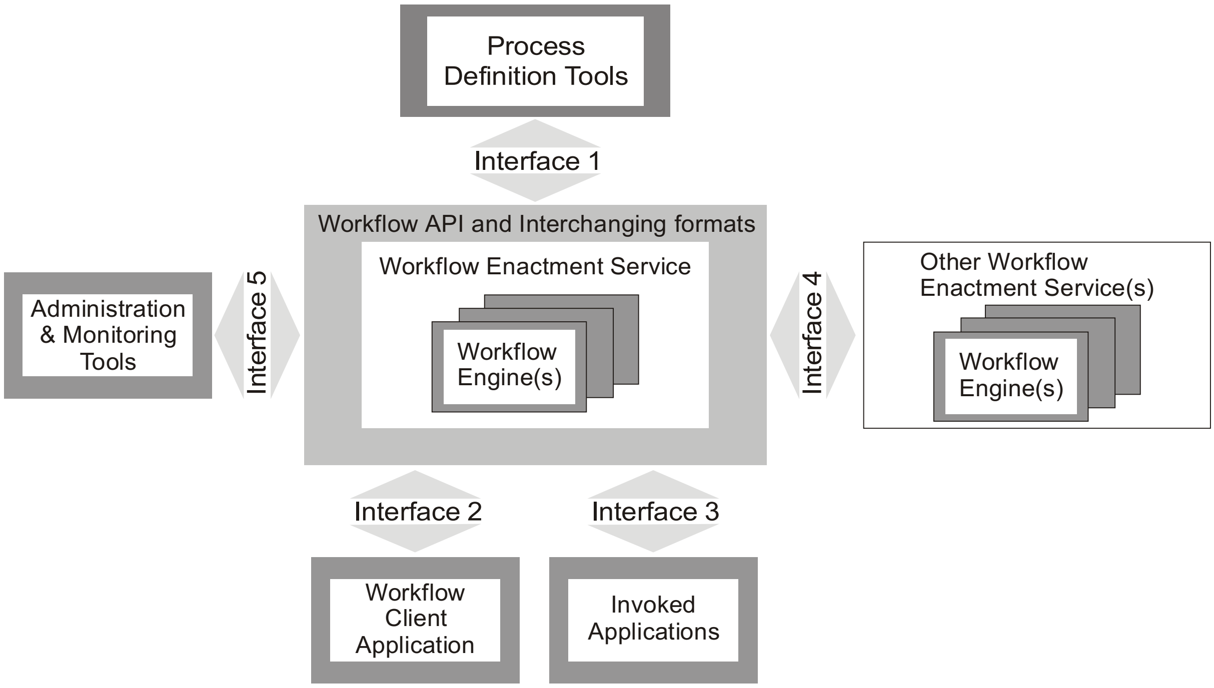

Fig. 2. Workflow Reference Model - Components & Interfaces [9]

The Workflow Enactment Service (WES) contains one or more Workflow Engines responsible for creating, managing and executing workflow instances from workflow classes. This central service is connected with five others components by interfaces specific for each of them (Fig.2). They are the following:

- Process Definition/Builder Tools allow implementing real world processes into the workflow. *Interface 1* specifies format of process definitions comprehensible by the WES.
- Workflow Client Application allows invoking and controlling activities and data in the workflow. It can contain and invoke the subworkflows responsible for several parts of the real world process. It uses *interface 2* to control interactions between a workflow client application and local WES or the other ones (by *interface 4*).
- Invoked Applications described by workflow activities are invoked by workflow engine in the way described by *interface 3*.
- Other WES can interact with a local one using *interface 4*. The interface describes manner of initiation, execution of its workflow activities including some related administrative functions too.
- Administration & Monitoring Tools allow monitoring of workflows activities and data flows in the way defined by *interface 5*.

Most of described functions have graphical interfaces, which allow simple management of workflows, their activities and connected data. Activities can stay in one of the following states:

running – the application invoked by activity is started and activities related to it are blocked;

executable –all data necessary to run activity are ready and all outputs of it are available;

stopped – application related to activity is stopped. States of its inputs and outputs are not changed. The activity can be restarted or cancelled;

completed – application invoked by activity has been completed successfully, new data appear on outputs, so related activities become executable;

blocked – inputs or outputs are not accessible, so activity can't be run.

4. IP DESIGN AS A PART OF A DISTRIBUTED DESIGN PROCESS

The methodology currently applied at the Institute of Electron Technology (ITE) is well known among IP providers. Each IP component is modelled at the RT level with VHDL. The model is developed as reusable IP - parameterised and possibly configurable. The component model is then verified by simulation. Several VHDL-based tools can be applied at that design stage. Next, the verified model is synthesised in a selected FPGA technology. As the result of logic synthesis, a netlist of hardware components is obtained. The next step is implementation of this netlist into a selected type of FPGA device.

A configuration file is obtained after placement and routing in a programmable array. Final verification of the component model is made by simulation of a VHDL model obtained from a back-annotation process, and final validation of the IP – by testing the configured FPGA device on an application board using a tester.

Fig. 3 presents a simplified IP design process from the workflow point of view, without any verification and testing procedure.

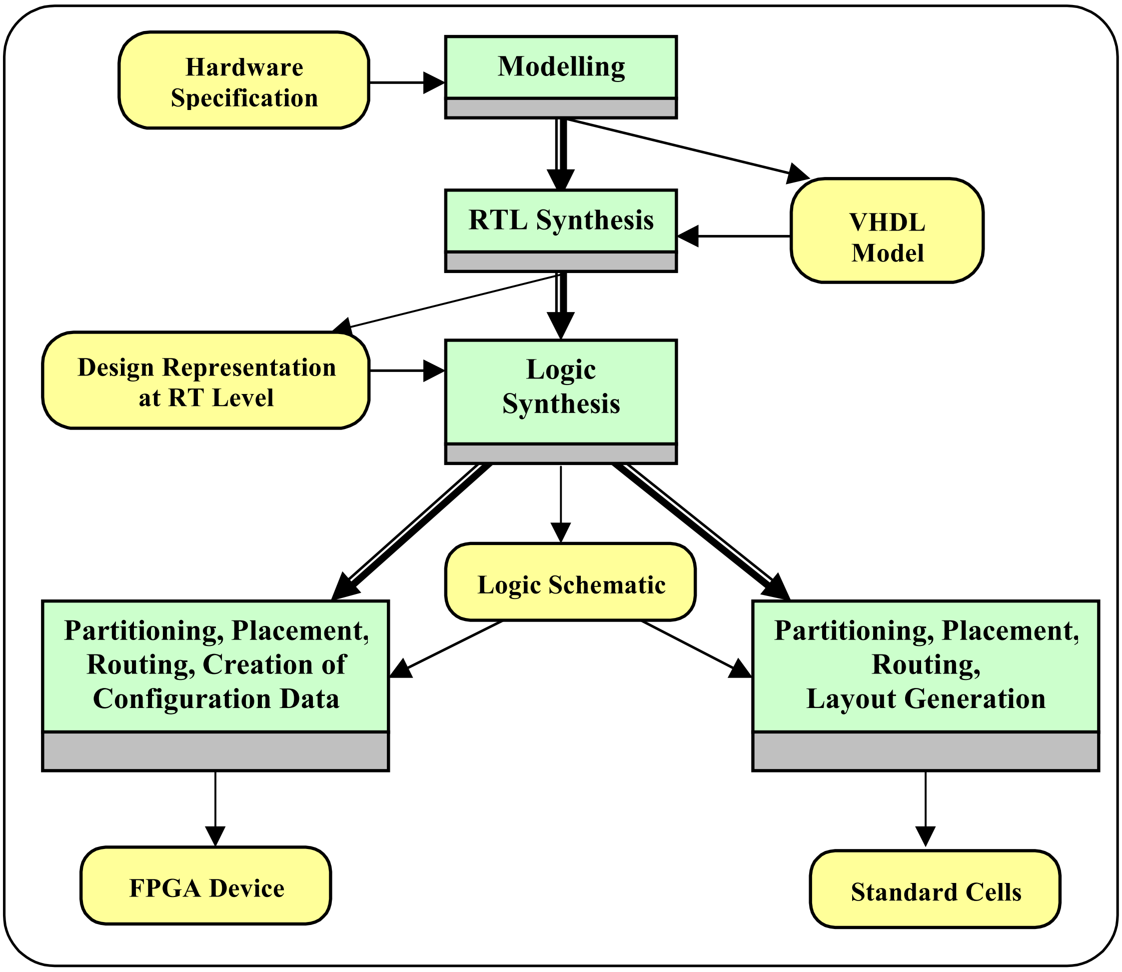

Fig. 3. A simplified IP design process from the workflow point of view

5. DESCRIPTION OF THE WORKFLOW

The workflow concept has been applied to a collaborative design of a digital camera specialised for medical applications. The new approach based on the ASTAI® integration system involves two E-Colleg partners: Thales Optronique (THO) - as the product developer and manufacturer, and ITE - as the IP provider.

The workflow specification integrating all tools used in the IP design process is developed at ITE and THO. Fig. 4 shows the specification schematically divided into three phases that correspond with three Workflow Enactment Services implemented on different platforms: UNIX Solaris and Windows NT. Detailed specification of the whole design process is necessary before defining a workflow.

The first phase that will be performed at THO contains requirements and design specification that will be implemented in hardware or software depending on system co-design results and performance evaluation. After the HW/SW partitioning, hardware IP component specifications files and binary reference test files will be transferred to ITE using ASTAI® infrastructure. ASTAI® use CORBA to communicate between WES and CORBA specification describe *interface 4*, it describe also this part of *interface 5,* which is responsible for control of WES communication.

The second phase will be performed at ITE, where VHDL code of the IP is generated. The test vector is used in simulation process of the developed VHDL model. The validated IP component model and related reports will be transfer to THO after execution the whole ITE part of the workflow.

At the last phase of the design process, all developed IP components will be integrated by THO with others electronic components (e.g. memories, processors) into earlier developed architecture of the digital camera. The validation of the system on board will be the last step of the camera design.

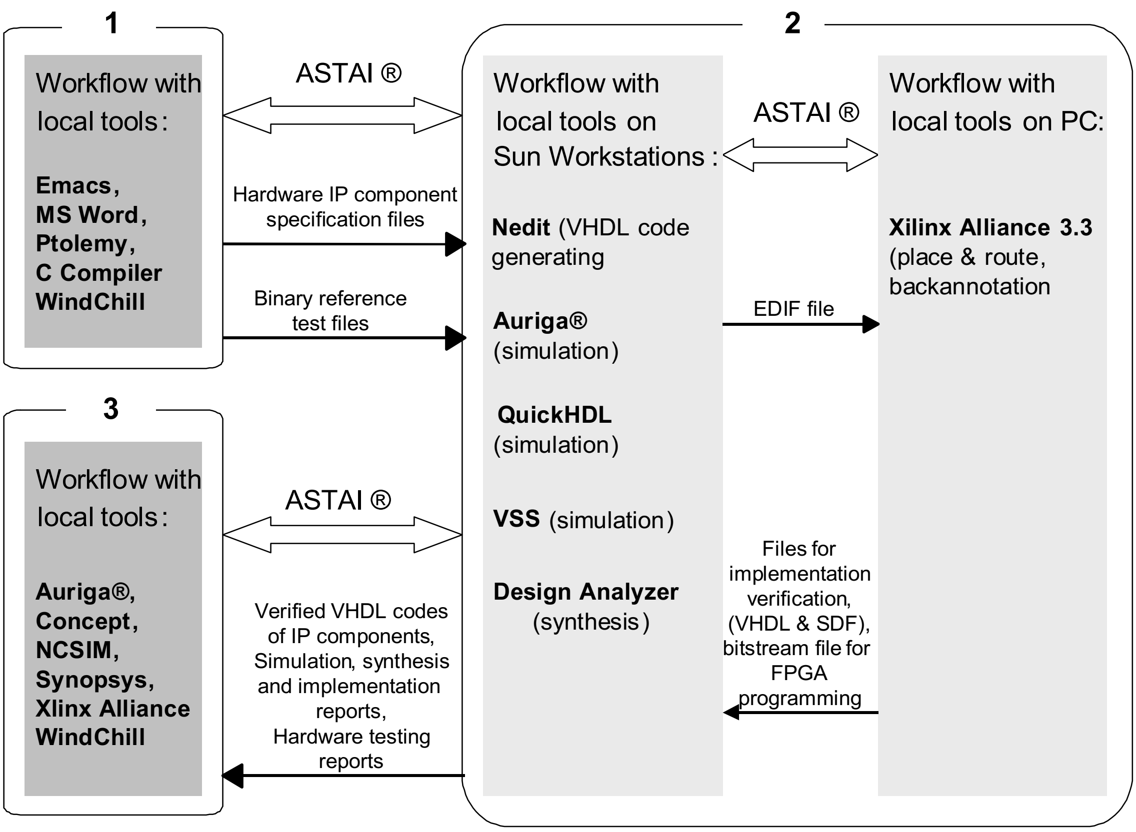

Fig. 4. Workflow specification

6. Deployment of the workflow in the ITE design environment

Some details of the workflow performed in ITE are demonstrated in Fig. 5. It contains successive activities executed during the design process. ASTAI® use TES to invoke applications by activities, so *interface 3* is described by TES specification. TES specifies also *interface 1* and part of *interface 5* responsible for workflow activities and data flow inside WES. The workflow integrates two simulation tools: Synopsys VSS and Mentor Graphics QuickHDL, which can be alternately chosen, and one synthesis tool - Synopsys Design Analyser. The synthesis process produces an *edif* file for XILINX Foundation implementation tool that will be executed in the section of the workflow on NT Windows platform.

The first part of the workflow showed in Fig. 5 is responsible for selecting and editing source, library and test files. A designer is given the possibility of creating a new file, choosing an existing one with or without editing it. Moreover, he can add selected file into the list of files associated with the workflow. At the moment the chosen file is automatically added into two lists: the first one with files for simulations and the second one with files for synthesis. After that, selected files are copied into workflow subdirectory; so each workflow has its own copy of them. So it is impossible to change source files used in one workflow by another one. The user can change the file position in appropriate file list for the purpose of modifying the order of the files to be compiled.

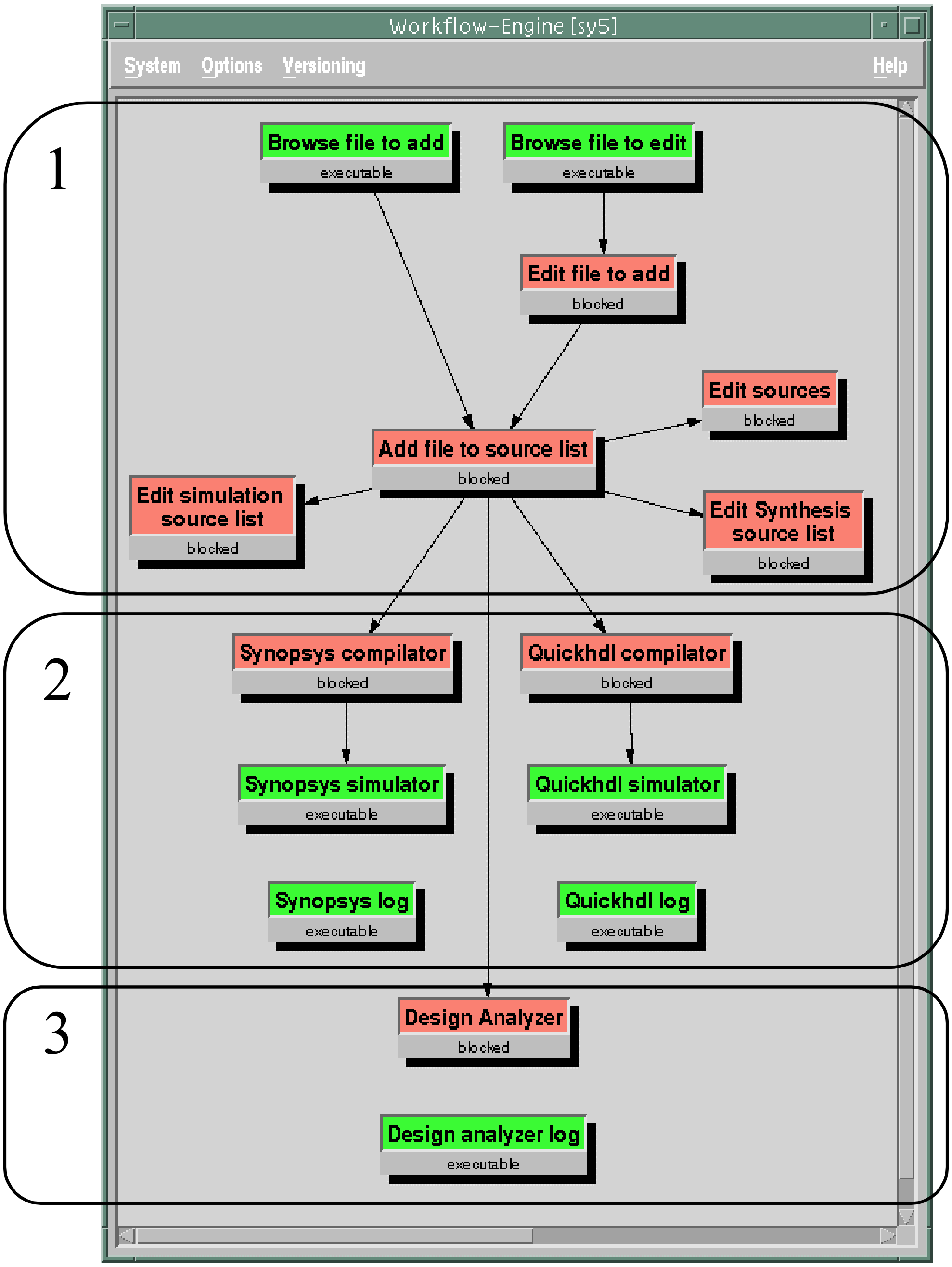

Fig. 5. The ITE part of the workflow executed on the Solaris platform.

The second part of the workflow is responsible for compilation and simulation of files from the simulation file list. The designer can choose if he wants to compile all files or to use the *makefile*. As the result of the compilation activity, the whole hierarchy of compilator specific directories including configuration files and the results of the compilation process, is created.

If the compilation process completes successfully, a designer can start the simulation and view its result. If the simulation is too computing power consuming, he can choose a machine on which the simulation should be done. All messages generated by compilation and simulation processes are redirected to associated log files. The user can view them at any time as required.

The third part of the workflow is responsible for synthesis. The designer has to put the name of the clock signal, the clock period, top of hierarchy for synthesis, and the name of the machine on which the synthesis process should be done (Fig. 6). All those items can be saved for future use. If the synthesis process completes correctly, the user obtains a file in EDIF format as the result of the activity. The EDIF file then can be sent to XILINX Foundation implementation tool working on the Windows NT platform.

The workflow can invoke all design tools from the NT platform, so the user can do all his work using a Windows NT machine. But if he wants to observe the simulation results from a UNIX machine, he should have Xserver installed on his Windows NT machine.

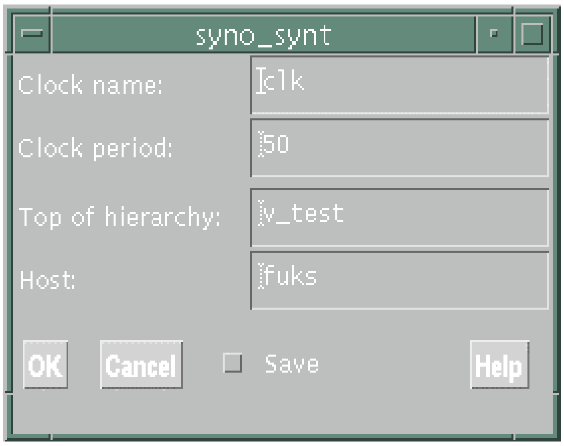

Fig. 6. Front view of the synthesis activity

The *data window* (Fig. 7) associated with ASTAI® environment shows internal data generated by the workflow activities. The user can trace the types and values of the data exchanged between particular activities. The data window gives him precise information about the state of data – there can be new data (first mark in column *state* in the data window), data can be valid or no (the second mark). He is also informed about current value of the data and which activities use it. Additionally, if the designer clicks on any row from data window, the related connection between activities depicted in Fig. 5 will be highlighted.

Fig. 7. The data window

7. Objectives and status of the E-Colleg project

The paper presents some workflow related experiments that are realised in the first phase of the 5th FP project E-Colleg (scheduled: 2000-2003).

The overall objective of the E-Colleg project [1] is to provide a new platform for distributed collaborative engineering through the definition and implementation of an advanced infrastructure that will offer sophisticated services for tool registration and management. In contrast to current industrial practice and available frameworks, this infrastructure and technology will consist of a set of interacting, location transparent services that can be dynamically configured and adapted to arbitrary tool configurations and location-independent design teams (changed consistency of the design team, transfer/delegation of tasks etc.) at run-time. A prototype of such infrastructure - ASTAI® platform has been provided to the E-Colleg consortium by Siemens Business Services (SBS).

The strategy for reaching the above objectives is based on R&D that involves profound validation of the infrastructure. This requires that it is actually used in sophisticated engineering tasks. Thus, in E-Colleg realistic from industrial perspective application scenarios have been carefully planned. They are part of product development processes of involved companies, i.e. Thales Optronique (France) and ITE research institute (Poland) in the case discussed in the paper. In addition, FTL Systems - E-Colleg partner will extend the developed collaborative environment by the Auriga® distributed simulation technology.

It is expected that lessons learned from E-Colleg will comprise a new design methodology taking full advantage of the distributed collaborative engineering paradigm enabled by the ASTAI(R) infrastructure and Auriga® technology. Other partners involved in the E-Colleg project are: Infineon Technologies (Munich), Silesian University of Technology (Gliwice), and University Paderborn.

8. Summary

Collaborative working in multiple-site, multiple-platform environments using traditional Internet-based tools (like *ftp* or *telnet*) is time consuming and error prone. The new approach based on a workflow concept gives new opportunities for efficient distributed engineering. Improvements are foreseen in two domains: reduction of design cost and reduction of design time.

In the paper, the collaborative design process of a digital camera has been presented. We have demonstrated the approach that creates the semiconductor IP in a distributed design process based on the ASTAI® environment. The future work will comprise the extension of the workflow to other design phases of the digital camera project, the generation of VHDL code of IPs, and the verification of specific services that are offered by ASTAI®.

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