A Web Services based approach for System on a Chip design planning

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Abstract: The concept of Virtual Organisation (VO) offers various solutions to management, collaboration and coordination issues important for distributed collaborating teams. Deployment of this concept to distributed electronic system design has been addressed in this paper. The article introduces an organizational model of a VO dedicated for System-on-Chip (SoC) design and an architecture of the supporting ICT infrastructure that has been based on the Web Services technology. The developed multi-tier distributed application supports interoperability of heterogeneous computer systems belonging to dispersed design partners. Implementation issues, as well as the experiments verifying the utility of the solution for SoC design planning are shortly reported.

1 Challenges in collaborative design of SoCs

Integrated circuits that incorporate whole electronic systems including microprocessors, memories, input/output interfaces, and other peripheral elements on one silicon structure are referred to in the literature as Systems-on-a-Chip (SoC). Due to rising complexity, strict "time-to-market" constraints, and heterogeneity of components, design of a SoC constitutes a challenge. It has been observed that the basic approach based on "design reuse", like Intellectual Property (IP) components-based design, needs to be strengthened through new technologies enabling collaboration in large distributed teams. This tendency is rising and since mid '90s is recognized as a new discipline named collaborative engineering. This new engineering paradigm becomes feasible due to more and more powerful Collaborative Working Environments (CWEs) that profit from recent achievements in information and communication technologies. Collaborative engineering is a cooperation of spatially dispersed engineers who as members of one distributed design team, work together towards a common goal. Their cooperation which is based on the Internet is virtual, highly flexible and gives them possibilities for fast communication, design data access, and information exchange. This form of distributed engineering can encompass large and distributed design teams. It can be thus viewed also from an organizational perspective. The very first examples of collaborative engineering were reported by large global companies. There the performed collaboration

included different branches within one organization. In this case many issues like, security or IPRs (Intellectual Property Rights) protection are less demanding, but integration of distributed engineers and their design environments still remains a challenge. Moreover the integration of design environments is even more difficult when we deal with an inter-organization collaboration. When distributed teams of designers belong to different organizations (especially SMEs) they may need to form a collaborative network in order to better respond to particularly demanding customers' requirements. We call this collaborative network a Virtual Organization (VO). Members of the virtual organization create an alliance to share skills or core competencies and resources. Their cooperation is enabled by dynamically developing computer networks [WP05]. In this case, an essential issue is a proper common ICT infrastructure that ensures interoperability of partners' CWEs. Thus, the goal of the work was to propose an architecture of this infrastructure, as well as to develop and verify its part concerning an initiation process of a Virtual Organisation dedicated to SoC design. This phase of the design project is very crucial for the overall success because a proper decomposition of the project into sub-tasks and selection of the most suitable partners for fulfilment of each sub-task influence directly the quality of completion of a single task, as well as the whole project [Wi06a]. The module supporting VO initiation and planning of a SoC design process was implemented in the C# programming language, as a distributed application with utilization of the Web Services (WS) technology. The application was developed for a VO active in SoC design.

2 Approach to SoC design planning problem

Nowadays design of a SoC is most often based upon reusable IP components that may stem from various sources. Often, many different organisations, including IP providers and system integrators must be involved in the design process. These are typically small design companies that are specialized in a certain type of products and which posses and operate specific design tools. Such a multi-organisational design constitutes a complex undertaking. It can be realised in different ways depending on a chosen design methodology or a chip fabrication technology. Below, we present an approach for conducting such a SoC design project within a specialised VO. This at the beginning requires adoption of a right management and assignment of appropriate roles to partner organisations. Project Manager (PM), the company which takes the project management within a VO, takes care of the whole project and plans it in details. PM can split the project into smaller or broader project tasks depending on the available its own and partners' resources and competences. Regardless of all these issues, the SoC design can be divided into the following main phases: 1) Preparation phase, 2) Functional design, 3) Physical design, 4) Prototype fabrication and testing. The architecture of the ICT infrastructure proposed further on is supposed to be useful during all these phases of the project. Nevertheless, in the paper we concentrate on the first one, namely: Preparation phase. The VO during this stage of the project is named Source Network (SN), because it is only a source of potential partners that need to be selected to form a virtual enterprise that will complete the remaining phases of the project. Firstly, we shortly remind the previously defined [Wi06a, Wi06b] basic management model according to which a source network has to function to reach its target which is virtual enterprise

initiation. Secondly, a proposal of the ICT infrastructure supporting the source network activities is reported in this chapter.

2.1 Organizational model of a source network dedicated to SoC design

A basic organizational model of a source network is a management model that illustrates a structure of the network, i.e. main nodes with their roles and functionalities. SN is a group of companies that joined their forces and developed a common preparedness to quickly respond to specific market needs and customer demands. Each company in the network plays a certain role according to the network architecture and a specific situation at a certain time. In the case of SN dedicated to SoC design four main types of member companies can be distinguished. These are: Network Manager (NMG) – preferably one company for the whole network, Network Broker (NB) – one or a few companies in the network, Project Manager (PM) – potentially all members, but in a particular moment, the company that won the competition for the project coordination, and Network Member (NMB). All network members during the preparation phase of the project have to fulfil their role-specific activities, which in general leads to the project phase completion and results in the design project plan [Wi06b]. The most important activities for each role are the following:

- **Network Manager**: maintenance of network knowledge (technical standards, standard network procedures related to the offered services), maintenance of the information about members' core competences and about available new projects, search for new network members and their registration;

- **Network Broker**: search for customers and collecting of external enquiries and orders, marketing of SN services and competences outside the network, organizing competitions for Project Managers;

- **Project Manager**: preliminary detailed planning of a project – determination of all sub-tasks and processes, virtual enterprise initiation (partners search and selection), coordination of the design project conducted by the virtual enterprise;

- **Network Member**: maintenance of the information about its core competences, tools, and available IP components, making offers for NB (applying for PM position) and PM (applying for project participant position), cooperation with PM and others NMB within a virtual enterprise which means project participation.

2.2 ICT infrastructure for source network

The proposed architecture of the ICT infrastructure is based on a multi-tier distributed application schema (Figure 1). It incorporates many different small applications running on different servers belonging to various network members. The idea is that these applications can co-work with each other and exchange data independently of the

platform under which they run. Computer systems belonging to network members include three main tiers separated from each other: Access Points – tier, Business Logic – tier, and Data – tier. Separation of the tiers between each other should give the possibility for accessing data from different access points regardless of the partner's platform and possibility for usage of the business logic running on the closest and most easily accessible server. The usage of the business logic belonging to a distant system which is a source of the required information should be also easily manageable. Separation of Data – tier ensures higher level of security. Access to it is possible only via a special business logic. An additional tier is the Web Services - tier that is a part of the Business Logic – tier. Web Services (WS) are software elements available on web servers (identified by URI), whose public interfaces are defined and described using XML. They can comprise business logic but they can be just a universal intermediate interface to the Business Logic – tier, thus giving possibility for its usage independently of the platform on which the business logic is running. In this way, Web Services give possibility for accessing data available only in internal systems of companies (e.g. ERP - Enterprise Resources Planning, PDM - Product Data Management, etc.). The key factor of the proposed ICT infrastructure, in addition to WS and the multi-tier architecture, is communication based on standards, like XML and SOAP. These ensure safe and reliable communication and interoperability between heterogeneous platforms and systems.

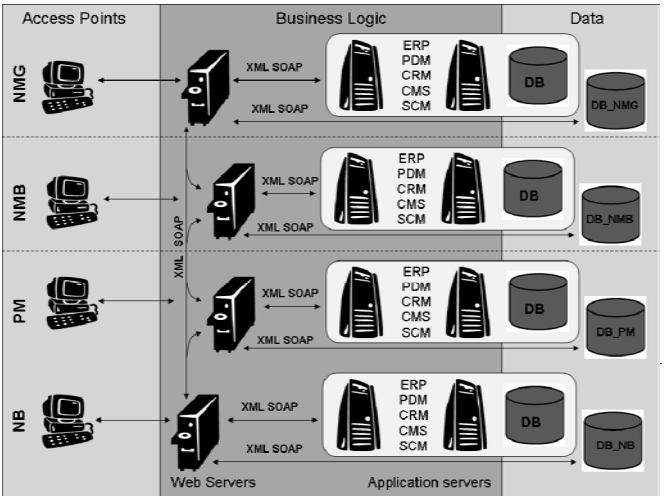

Figure 1: Overall architecture of the ICT infrastructure for SoC design VO

2.3 Preparation phase of SoC design

The ICT infrastructure sketched above supports planning of a SoC design managed by PM. The lists of design competences, design tools and IP components required for the project are created based upon the project specification received from NB. Next PM searches for partners within data stored on NMG servers and the listed design requirements are taken into account (Figure 2). In this way a list of potential partners is

created. Then PM using a simple application, that can be also a web service, generates a preliminary plan of the project which includes several sub-tasks and related to them design resources (i.e. competences, tools, IP components). Subsequently PM enquiries the bids of the best NMBs from the potential partner list. The enquired partners, but also all other organisations interested in the project, make the bids for participation in the project in respect to each of the project sub-tasks. PM with use of Multi Criteria Decision Analysis (MCDA) builds a ranking list of potential project participants for each design sub-task in the project (in view of partners' core competencies, available tools and IP components, offered costs and time for a task fulfilment, as well as its own past experiences with the considered partner). As a result a plan of the project realization including all sub-tasks and potential partners is achieved.

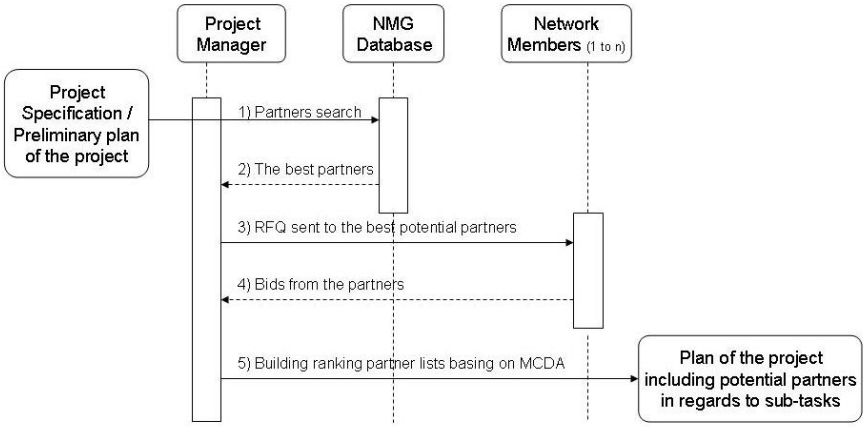

Figure 2: Preparation phase of the SoC design

3 Web Services - based distributed application for SoC design planning

As a part of the proposed ICT infrastructure the module for design planning and partners selection used during the preparation phase of the SoC design was implemented. The implementation platform was MS Visual Studio 2005 with the C# programming language.

3.1 Data – tier

The overall architecture of the system was simplified for the implementation and demonstration aims. The application doesn't include any legacy system, like ERP or PDM. The only sources of partners' internal data are databases that constitute the Data – tier of the application. This tier consists of several relational databases activated on MS

SQL Server 2005. Database structures were designed according to each member's role. The Network Manager database (NMG_DB) comprises information about available projects and all registered partners and their resources. Network Members' databases (NMB_DB) incorporate all detailed information about design resources (i.e. competences, tools, IP components) of the database owners. The Project Manager database (PM_DB) contains a table with PM's evaluation of trust to all NMBs and a single project specific information, like: the basic plan with sub-tasks, required resources, the potential partner list for the project, information about commercial offers of the partners (cost, time), and the final table with ranking lists of partners in regards to each sub-task (Figure 3). The relational data are easily and automatically serialized to XML that is a proper format for data exchange with Business Logic – tier via the SOAP protocol thanks to ADO.NET special data access layer that is a part of MS Visual Studio 2005 platform.

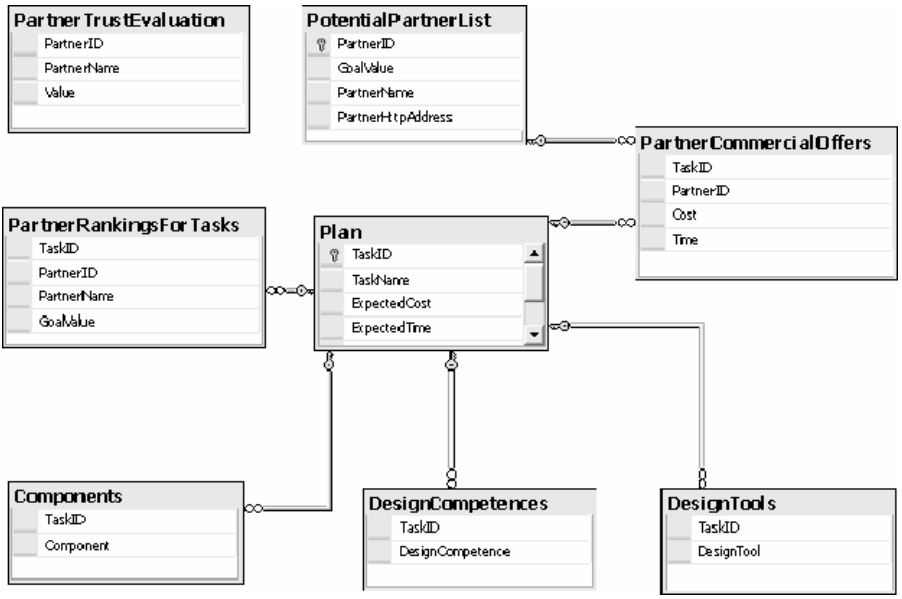

Figure 3: Structure of the PM_DB including information on a single project.

3.2 Business Logic – tier

Business Logic – tier consists only of web services that process data received from databases in the XML format using the SOAP protocol. The result of the processing is either sent to the user interface that is a Windows application, or is an input data for another web service. All services used in SoC design planning and their locations are the following:

WWW PM server:

- **MakePreliminaryPartnerList** - creation of potential partner list based on services and data from NMG_DB,

- **GenerateSubTasks, SetPreliminaryPlan, GetProjectPlan** – semi-automatic generation of preliminary project plan including all sub-tasks,

- **SetBidExpectations** – setting by PM the expected values of the costs and time for different sub-tasks,

- **GetBids** - receiving and saving in PM_DB the offers given by NMBs,

- **MakeProjectPlan** – building ranking lists of potential project participants for each design sub-task in the project (needed for final plan creation).

WWW NMG server:

- **GetPartnersInfo** – giving access to data about different NMBs (PM fills in a form about required competences / tools / IPs and then database search is performed),

- **GetProjectList, GetProjectDetails** – giving access to data about potential projects.

WWW NMB server:

- **SetCommercialOffer** - preparing an answer to PM's request (RFQ) for commercial offer (costs, time) and for information about partner's competences and resources in respect to a specific project and its sub-tasks,

- **GetCommercialOffer** – giving access to data about partner's competences, resources, and a commercial offer prepared for a specific project and its sub-tasks.

The whole communication between Web Services and Data – tier or Access Points – tier is based on XML and SOAP due to usage of special data containers called DataSets. The DataSet component is a part of WS and includes proper methods and the XML schema that are adequate to DataSet's structure. This enables an easy serialization of data to and from the XML format when it is sent or received. User interfaces, forming the Access Points – tier, were created as simple Windows applications. Their main goal was to present the results achieved by Business Logic - tier or for entering data to this tier. Due to communication based on XML and SOAP the results from Business Logic - tier could have been exposed also in applications running under other systems or in web browsers.

3.3 Partner selection optimization

Partner selection optimization utilizes an algorithm based on Multi-Criteria Decision Analysis [Ja05, LMS05]. According to this method each partner is evaluated taking into account several criteria. In the first stage of evaluation, when the preliminary partner list is created, the following criteria are used only: design competences, design tools, IP components and the evaluation is made based on data coming from Network Manager database (NMG_DB). During the final, main stage of the partner selection, when the

partner ranking lists in respect to each sub-task are created, the additional criteria are taken into consideration: offered time, offered costs, and PM's trust (Figure 4). For partners evaluation an objective function, that includes weights (w) and values (v) for each criterion, is calculated for each partner:

$$V_{j,i} = \sum_{m=1...6} w_m v_m^{j,i} ,$$

where the index "*j"* denotes the evaluated partner (j= 1…n), the index "*i"* indicates the number of the sub-task being under consideration (i=1…k), and index *"m"* says about the number of the criterion evaluated (m=1…6). During the main evaluation process the values (v) judging partners' competences and resources are collected from the partners' databases (NMB_DB). The values evaluating their commercial offers are given by PM.

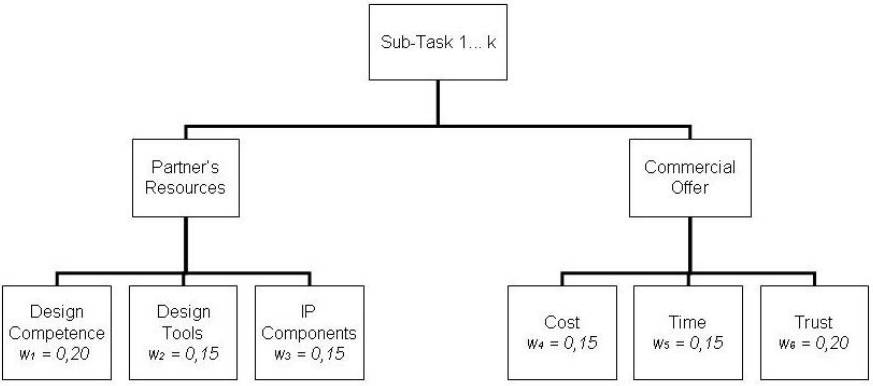

Figure 4: Hierarchy of criteria used during partners' evaluation.

4 Design planning experiment and its results

The MP3 player design plan was the objective of the experiment that was performed in a small LAN that imitated the Internet. Database servers (MS SQL Server 2005) and web servers (MS Internet Information Services) were installed on three computers regarded as servers belonging to the source network members with various roles (Figure 5). The database tables were filled in with example data describing resources of different partners (i.e. design competences, design tools, IP components) which during the experiment served for partners evaluation. The web servers were loaded with web services corresponding to the roles of partners (PM, NMB, NMG). A preliminary specification expressing the general requirements for the system was turned into the lists of the competences and resources required, which subsequently with help of the proper web service gave a preliminary project plan with six main sub-tasks (Figure 6).

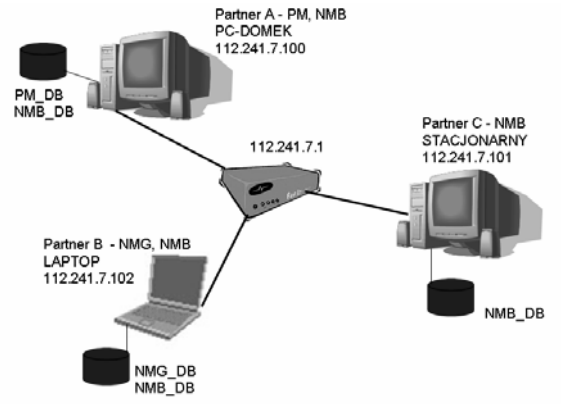

Figure 5: Experimental environment – a source network structure.

During the experiment the partner search and selection processes were simulated several times for different input data, i.e. various commercial offers of partners for the MP3 player design. This showed the influence of the chosen decision model, including criteria hierarchy and criteria weights, on the results achieved and proved its usefulness for the appropriate partner selection. The demonstration showed additionally an agile WS – based distributed application performance with easy communication based on XML and SOAP within a network environment through firewalls. For the given SoC specification the software resulted with a semi-automatically generated plan of the project with ranking lists of potential partners selected for each single sub-tasks included in the plan (Figure 7).

Sub - Tasks	Design Competences	Design Tools	IP Components
Functional design	Functional System Design	MG ModelSim Logic Sim	
IP components collecting and integaration	IP Components Collecting IP Components Integration	MG ModelSim Logic Sim	Microcontroller 16 bit Decoder Audio MPEG DAC converter 24 bit
Simulation	Functional Simulation / Verifcation	MG ModelSim Logic Sim	
Synthesis	HW High Level Synthesis / Optimization	Synopsys FPGA Compiler MG Precision RTL Synthesis Synplicity Synplify	
Implementation	Place & Route Timing Analysis FPGA Programming	Xilinx Foundation ISE FPGA place-and-route generic tool Synopsys Prime Time	
Tests	In-System Testing		

Figure 6: A preliminary project plan divided into several sub-tasks for MP3 Player design

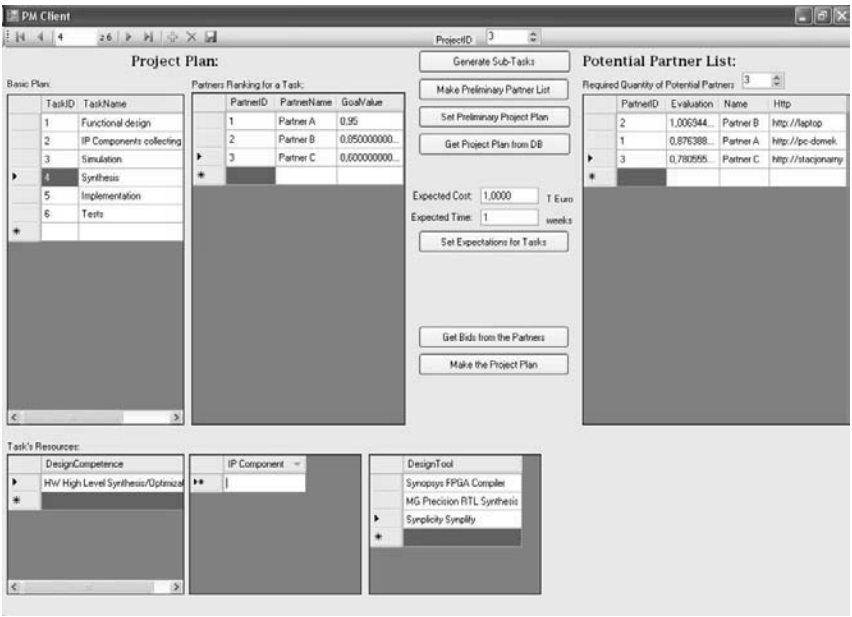

Figure 7: An example of PM user interface showing the potential partner list for the project (on the right side) and the partner ranking list for sub-task 4 - Synthesis (on the left side)

5 Summary and conclusions

The presented solution aims at supporting SoC designs performed by distributed design teams within virtual organizations. According to the current state-of-the art analysis, similar solutions dedicated for this branch of industry haven't been deployed in engineering practice yet. However, there are corresponding solutions [CAO05, AGC05, At06] developed by research projects or commercial software companies that can be used for managing VOs of other types, like those operating in construction industry or tourism. These solutions are based on different software technologies and tools. First solutions dedicated for VOs and especially for source networks were proposed roughly a decade ago and utilized technologies, like: RPC, CORBA, RMI, EJB, Jini, DCOM [CAO05]. Due to the fact that they worked mostly with their own communication protocols they weren't good for work with heterogeneous systems and did not get a broader acceptance. Other attempts were based on multi-agent systems [CAO05]. Current research directions in this domain [AGC05, At06] point to Service Oriented Architectures (SOA) and the usage of common standards, like XML, HTTP, SOAP, WSDL, etc. together with the WS technology. Our solution in accordance with these trends is based on SOA and WS. It demonstrates a possibility for an agile partners search and selection within a distributed environment of the source network. The Web Services - based approach has advantages among which the most important is cooperation of partners with heterogeneous computer systems that communicate between each other

using common standards, like XML and SOAP. Additionally multi-tier distributed application provides access to data from different access points including mobile devices with a proper user interface. It ensures also higher level of security, and gives access to company internal systems data via Web Service – tier.

The implemented software demonstrator showed how SoC design project can be planned with a semi-automatic manner taking advantage of distributed data. An additional value of the solution is the optimization of partner selection based on methods of Multi-Criteria Decision Analysis. The proposed hierarchy of criteria has proved its utility for partner selection for a SoC design. Despite it, the method and the infrastructure could be also used after small adaptations in other industry domains. In general, the system simplicity comparing to competitive solutions gives the possibility for easy realization of main functionalities required in the source network. Existing comparable solutions based on SOA and WS are either commercial software dedicated for large corporations and their partners, or complex solutions for VOs which are still under development by research project. The presented organizational model of the source network and the supporting ICT infrastructure make the collaboration of distributed SoC design teams more efficient. It is due to easier implementation of the „Design by Reuse" paradigm, usage of know-how of distributed professionals employed by partners of the source network, common usage of distributed design tools, and support for more efficient and faster preparation phase of the project.

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