Network of Excellence

IST-004527 ARTIST2:
Embedded Systems Design

Activity Progress Report for Year 1

JPIA-Platform:

Platform for Component Modelling and Verification

Cluster:

Modelling and Components

Activity Leader:

Susanne Graf (Verimag)

Integrate the relevant European research on modelling and analysis of component-based real-time systems by building a tool supported semantic based platform for standard modelling notations that are relevant for the design of embedded systems.

This platform will support transformations to semantic kernel languages to leverage associated powerful analysis tools, in particular some of those from the "Testing and Verification" cluster.

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0. Foreword to the revised version

Since the start of the NoE, there have been some slight shifts in the detailed objectives of the platform activities, partially due to the merging of the Hard Real Time and the Modelling and Components clusters: we had initially considered the possibility to unify a set of UML profiles in the context of the activities on the MARTE profile, in which most of the platform partners participate in some way. But very quickly, it became obvious that this profile can solve only a part of the problems (it is mainly made for providing a set of annotations for timing analysis).

In this platform activity we intend mainly to experiment with semantic level formats onto which UML specifications are be mapped for analysis. This work will be done in collaboration with the semantic platform activity.

The second issue is to experiment to which extent analysis and validation tools can be shared between different but related contexts. One objective of the jETI platform is to help a user to find with the help of a tool domain model appropriate usage scenarios for a given set of available tools.

The main Revisions in this document:

- Elimination of some typos and other minor modifications
- Correction of figure which had a problem due to the doc to pdf translation
- Elimination of ambiguous formulations concerning the objectives and technical description of this activity (section 2).
- More detailed description of the components being part of the platform (section 3.1.)
- Explicit paragraphs concerning the problem of language integration and tool integration have been added in section 3.2
- Collaboration between partners is mentioned explicitly in section 3.6 instead of just implicitly in terms of the contributing collaborative projects in section 3.5
- For the state-of-the-art concerning UML profiles a pointer to the deliverable of the MARTE standardization activity is given. An overview on the set of existing UML profiles is not the focus of the platform activity, and a detailed account on that issue is already given there.
- In section 4.3 on ongoing work, the contribution of the individual lines of work to the platform has been identified more clearly

1. Introduction

1.1 Activity Leader

Team Leader: Susanne Graf (Verimag)
Areas of her team's expertise: Semantic level modeling formalisms, validation platforms of real-time and embedded systems, framework for component coordination.

1.2 Clusters

Components
Hard Real-time
Adaptive real-time

1.3 Policy Objective

The platform work builds on work on UML modeling lead by INRIA and CEA and work on semantic frameworks by the teams in the "hard real time components" cluster and the participants in the "semantic platform" activity.

This platform will support embeddings of user level system modeling notations in semantic level kernel languages to leverage associated powerful simulation and analysis tools, in particular some of those from the "component" and the "Testing and Verification" cluster.

1.4 Industrial Sectors

Relevant to most industrial sectors in which system modeling and model-based development is relevant, such as Aerospace, Telecommunication, Automotive, Industrial automation, Smart Card Applications.

Throughout the first 12 months, we have had active participations from associated Artist partners in the form of collaborations and case studies from Telecommunication (France Telecom R&D) and Aerospace (EADS launch vehicles) who are considering the introduction of UML based modeling in their development cycle in addition to, or as a replacement of their present approaches.

2. Overview of the Activity

2.1 Artist Participants and roles

Team Leader: Susanne Graf (Verimag)
Contributions of her team: Semantic level modeling formalisms, IF validation platform for real-time and embedded systems

Team Leader: Jean-Marc Jezequel (INRIA)
Contributions of his team: UML-based model transformation technology.

Team Leader: Sebastien Gerard (CEA)
Contributions of his team: Definition of UML modeling notation. CEA model transformation and analysis tools

Team Leader: Pierre Combes (France Telecom R&D)
Contributions of his team: connection of performance analysis tools to UML case tools.

Team Leader: Bengt Jonsson (Uppsala)
Contributions of his team: Connection between modeling and verification tools, Times tool

Team Leader: Noel Plouzou (INRIA)
Contributions of his team: Model transformations and aspect orientation, tools

Team Leader: Bernhard Josko (OFFIS,)
Contributions of his team: OFFIS UML validation toolset

Team leader: Alberto Sangiovanni-Vincentelli (PARADES)
Contributions of his team: Platform-Based Design, UML Platforms and the Metropolis framework

2.2 Affiliated partners and Roles

Team Leader: Julio Medina (U. of Cantabria)
Contributions of his team: connection to Adaptive real-time cluster, notations and tools for scheduling analysis.

Team Leader: Bernhard Steffen (University Dortmund)
Contributions of his team: tool integration platform.

Team Leader: Thierry Coupaye (FTRD)
Contributions of his team: Fractal/Think and integration with validation tools.

Team Leader: David Lesens (EADS)
Contributions of his team: Case study on architecture modeling and schedulability analysis.

2.3 Starting date, and expected ending date

Started: September 1st 2004

Expected Ending date: end of the project

2.4 Baseline

UML is becoming a standard for model-based development, also in the context of real-time and embedded systems. However, at present, semantics foundations and tool support for analyzing and validating real-time embedded designs is still weak. In the context of real-time embedded systems, there exist a number of UML based CASE tools (e.g., Artisan, Rhapsody, RoseRT, TAU) and there exist also a large number of analysis and validation tools, mostly coming from academia. With a few exceptions, they are dedicated to specific profiles taking into account a small subset of UML and are weakly integrated in the development flow.

Several of the platform participants have already done considerable efforts for integrating analysis and validation into the development flow --- in particular in the framework of IST projects AIT-WOODES (CEA: Accord Methodology and tool support, OFFIS: verification tool for UML in Rhapsody), OMEGA (Verimag: IF verification tool for real-time UML, OFFIS: verification tool for UML), and Metropolis (PARADES: UML platform).

2.5 Technical Description

The aim of this activity is working towards a connection of existing tools into platforms for modeling and analyzing real-time systems using standards and de facto standards based on UML. The considered UML profile is the MARTE profile developed in the activity on "Development of UML for Real time" lead by Sébastien Gérard, possibly with extensions, and the Heterogeneous Rich component Model developed in the SPEEDS project.

For the interconnection of tools a semantic level platform using few but powerful concepts, will be used. It will be developed based on existing work: the Kermeta Format developed at INTIA, The Metropolis model developed by Parades and the IF/BIP component model developed by Verimag. This work will be coordinated with the activity on a "semantic Platform".

Standardization is *not* the objective of this platform activity. We rather aim at building tools that should be sufficiently open and flexible to be easy to adapt to different profiles.

In particular, different analysis tools, for simulation, verification, validation, and analysis of timing and other QoS properties (mentioned in the detailed work description), will be interfaced via a semantic level meta-model and generic tools transforming user-level models into semantic level models. We hope that this decoupling together with an appropriate choice of basic concepts at the semantic level will provide enough flexibility to adapt tools to new standards easily.

Input from case studies provided by associated partners, such as ABB, DaimlerChrysler, EADS, France Telecom R&D and Thales will set requirements for and validate the work.

2.6 Organization of the report

The remainder of the report is organized as follows.

Section 3 provides the report on the planning and coordination activities which have been supported by Artist.

Section 4 summarizes ongoing technical work done by the partners either individually or in the context of other collaborative projects.

3. Activity Progress Report

3.1 Work achieved in months 0-12

The main objective of the first year of the project was to obtain an inventory of potentially interesting tools, possibly to do some initial developments within these tools towards a possible integration and finally to define a concrete vision of the Artist platform for component-based design and validation. This has been done during the meetings hold in Grenoble in October 2004, in Paris in January 2005 and in Rennes, end of June 2005. The last meeting has been hold in common with the hard real time and the adaptive real time clusters.

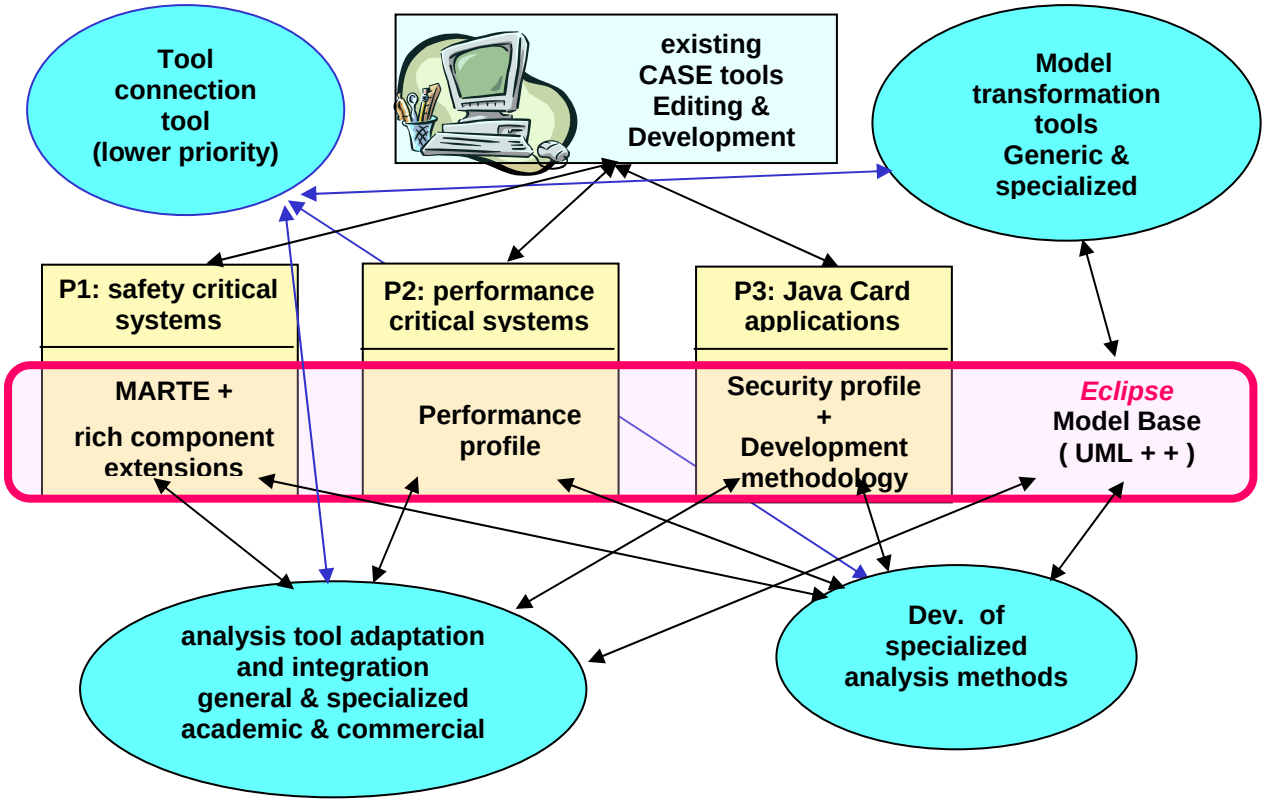

Fig. 1: architecture of the platform

We have chosen the option to first connect a restricted set of model-based analysis and validation tools with the help of tools implementing UML compatible model transformation technology and possibly – if this turns out to be useful – tools allowing to generate complex functionalities from basic ones by means of abstract specifications. The set of identified tools is always to be considered preliminary; new tools hopefully will join the platform over time.

Due to the large span of applications covered by the tools to be integrated into to the platform, this integration is not intended to be a strong integration in the classical sense of an integrated toolset, but rather a set of components that can be used in combination with specific components to form different tool chains. A baseline of the tools is that they are UML compatible and share subsets of UML profiles. Some components will be specific to particular tool-chains and whereas others are useful in several ones.

Presently considered tool chains used in case studies are identified by the following working titles:

- A platform for the analysis of safety-critical embedded systems. This platform will be developed mainly in the context of the projects OpenEmBeDD, Caroll and SPEEDS, with contributions from SAVE and ASTEC.
- A platform for the analysis of performance critical service-based systems. This platform is mainly developed in the context of the Persiform project. In the first year the main aim providing a mapping to a commercial performance analysis tool.
- A platform for the certification of smart-card applications. This platform is developed principally in the EDEN project and its successor EDEN-2.

The relevant subsets of UML used in the context of these three environments are specific for the concerned target application types. The first one will focus on system specifications, where behaviour of individual components are specified by means of state-machines and requirements by state-machines and possibly Sequence diagram. This Profile will consist of the MARTE profile and the Rich component concept to be developed in SPEEDS. The second platform will focus on early performance specifications described in terms of activity diagrams. It is being developed in the Persiform project. And in the third one, the main focus is on the expression of security properties which are developed in the EDEN project.

The performance annotations in platform 2 will use a subset of the timing annotations in MARTE. For the description of design specifications in platforms 2 and 3 (considered in a later stage), it may be interesting to consider a subset of the profile of platform 1, but this has to be studied further. Also the profile concerning architecture modeling may be shared, but will be considered later.

The analysis tools should in principle be sharable amongst the platforms thanks to the mapping into a semantic level model. Concerned are in a first place the tools Agatha (CEA) for scheduling analysis and test case generation, IF/BIP (Verimag) for simulation and verification of timed specifications, HERMES (Verimag) for the verification of secrecy properties, TIMES (Uppsala) and MAST (U. Cantabria) for scheduling analysis, OFFIS tools for model-checking, safety and fault analysis, and Metropolis (PARADES) for simulation and connection to external model-checkers like SPIN. There is some overlap in the functionalities of the validation tools, but they are based on different algorithms and have different strengths and weaknesses. Some new analysis methods, specific to the needs of the specific applications will be built.

The tool jETI (U. Dortmund) is intendend for a high-level integration of tool functionalities. It allows the specification of complex functionalities from functionalities provided by different tools. This kind of user level tool integration was totally absent in earlier projects and claimed by users. Also here it will not be the main focus, but started at a more advanced stage.

An overview on the initial version of the targeted architecture, indicating both shared and specific parts are given in Fig. 1 above. The developed tools will be ported to Eclipse.

During the first year of ARTIST, we have done only little integration. The main progress was on individual components for these platforms. A detailed overview on the work done and more detailed architecture is given in section 4.

3.2 Difficulties Encountered, risks and envisaged solutions

Tool integration is in general a difficult and risky task, because integration is fragile in case of evolution, and on the other hand, in particular in the context of rapidly involving standards, such as UML and its profiles, there is always a risk of “running behind the standard evolution”.

One possible option that has been considered in the very beginning was escaping to this problem by the definition of “our own standard” which would consist in the choice of a particular subset of UML with a well defined semantics, as this has been done already in a number of projects. We quickly concluded that this was not really an option, as it excludes too much of the existing technology in use. Therefore we propose to not pursue integration at language level but rather at semantic level.

The link from (standard) user level formalisms to semantic level framework is done by mappings from user level to tool level concepts, where the choice of the concepts at tool level is crucial: a main task of the tool level semantic framework is to be able to faithfully represent the composition concept of a user level language which includes component interaction and coordination, whereas we may rely on the different modeling tools for providing an executable semantics of individual components.

To alleviate the tool integration problem in general, we have chosen to go for a “lightweight” integration that already proved to be successful and that is based on the following principle: a platform consists of a set of tool components implementing different functionalities and sharing a common semantic level framework as already explained.

As an integration framework at tool level, we have chosen Eclipse as this seems to be the general trend. There are already UML tools integrated in Eclipse (e.g. the Rational tool), but also other important vendors (e.g. Ilogix, TNI or Esterel Technologies have recently made commitments to port their tools to Eclipse).

Obviously, one will always have to cope with the problem of standard evolution. Nevertheless, we hope that the semantic level format to be developed, which we expect to be more stable, allows some decoupling the back-end analysis tools from language evolutions. Syntax directed analysis however, such as static analysis and abstraction, need to exploit a relatively rich set of high level concepts. For this purpose, we expect that generic model transformation technology (actively developed at the INRIA and CEA team, in particular in the context of the OpenEmBeDD project).

In addition, platform developments require sizable budgets that are not available in this activity. During the first year, we have started the preparation of the French RNTL project OpenEmBeDD) and the IP SPEEDS, which have meanwhile have been accepted and allow us to start working.

Due to the fact that the main finances come from a set of individual projects (each of them including several of the platform partners) there is a non negligible risk that the immediate needs of the individual projects will have some priority over the common long-term goals worked out in the context of Artist. Nevertheless, the fact that a common solution will help several partners to share forces will hopefully counter balance the tendency for divergence.

3.3 Recommendations

Given the collaborations that have been established during this first year of ARTIST with the participants of the Hard Real time cluster, in particular INRIA and OFFIS, and due to the fact that on one hand the activities in the hard real-time cluster are strongly oriented towards component-based systems and the “platform for component modeling and verification” is aimed at the same application domains, we propose to continue the platform activity within the new cluster which will increase the importance of the platform for safety critical systems.

3.4 Milestones

The first important milestone consisted in the identification of the interesting existing tools and the definition of the envisaged platform and the components to be integrated. The introduction of a semantic level format is an important progress with respect to work done in earlier projects (WOOODDES, OMEGA, and SAFEAIR).

3.5 Main Funding

The funding for the coordination and planning work reported above as well as the meeting and deliverable preparations have been funded by Artist2 (with the exception of a few travels paid with other resources). The funding for the development of the platform components, reported in Section 4 come from the following sources:

- the CARROLL initiative, a common research program between Thales, CEA and INRIA
- Families (for CEA, INRIA, Thales), ITEA European project on component based modeling of product lines;
- EDEN (for CEA, Verimag), French national RNTL project on UML based development and verification of security critical system;
- STACS (for CEA, Thales), French national RNTS project on validation and testing of component based models;
- CLIPS (for CEA), French national RNTL project on component based development of production systems.
- PERSIFORM (for FTRD, INRIA and Verimag), a French National RNRT project on functional and performance analysis of service oriented specifications
- OMEGA (for VERIMAG, OFFIS, FTRD), IST FP5 project (terminated since February 2005).
- SAVE (for Uppsala), Swedish national project on component based development of embedded systems.
- ASTEC (for Uppsala, ABB) on component-based modeling of embedded control systems
- From 2006 on, there will be OpenEmBeDD (for CEA, FTRD, INRIA, and Verimag), the aim of which is the development of an open source platform for providing model based engineering technologies for the development of real-time embedded applications.
- During the first half of 2006, will start the SPEEDS IP project, with the Artist partners IRISA, OFFIS, PARADES and Verimag and affiliated industrial partners Daimler and IAI.

3.6 Indicators for Integration

We consider the collaboration between the partners of the platform activity to be very good. Most of the core partners collaborate with several other core partners in different collaborative projects on the topics directly related to the platform activity (as can be seen from the list of projects in section 3.5). The affiliated partners have either strong connections to at least one of the core partners (such as U. of Cantabria) or bring in missing competences (such as U. of Dortmund with their tool integration tool). In addition to the already mentioned projects allowing financing our activities, several more informal collaborations exist, for example

between Uppsala and Dortmund. Some concrete collaborations that have taken place in the first year include:

- Collaboration between CEA, INRIA and U. Cantabria on the MARTES profile
- Collaboration between CEA and INRIA on model transformation
- Elaboration of a common semantic model for activity diagrams between INRIA, FTRD and VERIMAG
- Collaboration between OFFIS and VERIMAG on an UML profile and validation tools (in Omega)
- Collaboration between FTRD and Verimag on porting THINK to BIP/IF
- Collaboration between CEA and VERIMAG on profiles and tools for security protocol validation (EDEN).

We would like to mention that the platform activity had a very positive effect on the collaborations amongst Artist partners which would have been impossible to achieve without the existence of Artist. In the future we expect to have stronger interactions with the partners of the activity on "*Merging the event- and time-triggered paradigms"* addressing problems that is crucial for the integration of synchronous and asynchronous approaches.

Interesting new collaborations concern particularly, new interactions between specialists in modeling in model-transformation technology, specialists in real-time systems and specialists in analysis and verification techniques. For example, due to Artist, a French national project OpenEmbeDD on both aspects, including all French Artist participants, is starting. In addition, SPEEDS IP on Speculative and Exploratory Design in Systems Engineering emerged from an initiative of a set of Artist partners. These two projects will further elaborate on the definition of *semantic level formats* and scalable validation tools which will be coordinated in Artist in the "*Semantic Platform*" activity and contribute to the "platform for component modeling and verification". These projects involves also important tool builders, such as Esterel Tech., I-Logic, TNI and Extessy which will hopefully allow us to increase the impact.

The organization of the workshop MARTES in association with MoDELS'2005 is another indicator of collaboration between these communities.

3.7 Evolution

The main aim in the next 18 months is to provide initial versions of the three planned tool-chains based on existing UML extensions for real time, as well as the definition of a semantic profile, suitable for analysis tools and simulation, as well as some of the needed mappings, integrating some forms of abstraction.

The tools will be demonstrated on some case-studies.

3.8 Interaction, Building Excellence between Partners

A lot of interaction between partners took place within the projects mentioned in section 3.6. In addition, three global meetings have been held to discuss ongoing research and tool development activities and in order to coordinate --- as far as possible --- the work done by the partners, and finally to elaborate a plan for an initial version of the platform as well as the agreement on the main focus points.

The common meetings allowed all partners to get a better understanding of each others activities which was very helpful for working out the main focus points of the platform. The MARTE profile, which was at some point of time considered as a possible candidate for a common profile, was recognized as an important contribution for enhancing models with analysis related annotations.

It may also contribute to some extent for the expression of interaction and execution modes, but we came to the conclusion that a set of semantic level concepts for interaction and coordination are needed for a possible integration of heterogeneous models. An important outcome of the 3 meetings of the partners involved both in the development of component frameworks and in the platform activities, is the agreement on some priorities which include the needs for support of compositionality by means of rich interfaces and separation of orthogonal concerns by means of multiple viewpoints. Starting points for this are the Kermata model developed at Irisa, the component framework proposed by Verimag and the Metropolis model.

Notice that the yielded semantic formats are mainly meant for validation by state space exploration, their strong point being the coordination of components with some given interaction model. The separation between the component behaviour and the component interaction will in addition provide means for abstract global analysis and compositional analysis of high-level abstractions.

Another important outcome are two project proposals on tool integration, in which Artist partners play a key role. The first one is the French project OpenEmBeDD on the development of a platform for the development of embedded systems based on model-transformation technologies that builds upon the outcome of collaborations started in Artist. The second one is the IP SPEEDS, based on the quite similar grounds, and with a very strong involvement of commercial tool builders and users, in particular in the domain of automotive and aerospace, as well as their suppliers.

3.9 Spreading Excellence

The results described in the next section are done with some coordination and are obtained by collaborations amongst groups of Artist partners, involving in general research groups and industrial partners outside Artist. Thus, Artist influences a large number of the visible research groups active in these topics in Europe.

The members of the Artist team are involved in the organization and in the programme committees of the leading workshops and conferences in the domain, and publish their work in the relevant conferences and journals.

Cluster members organize together with external partners the MARTES workshop held within the Models 2005 conference which has been very successful. The topic of the workshop are modeling and standardization issues pursued in Artist as well as corresponding tool support; several interesting presentations have been given on both subjects; two of them have been chosen for publication in a post conference volume of all the workshops held together with Models 2005.

ARTIST2 teams of this cluster are involved in other national and international projects involving the main tool builders or where the standardization issues are a key point such that we can be reasonably confident that the issues raised by and the results provided by our platform activity will have impact on tool builders and on the standards where needed. These projects include in general also industrial *users*, applying the developed technology on case studies. In the past this turned out to be an excellent vector for the transition of academic technology into industrial practice.

4. Detailed Technical View

4.1 Brief State of the Art

The state-of-the-art relevant for this activity concerns the existing tools for model-based engineering and validation of functional and non functional properties, as well as the status of component based approaches and heterogeneous designs using different paradigms for different components instead of a uniform approach. The idea is not to provide an exhaustive state-of-the-art, but only to provide the essential facts for motivating the workprogramme of the platform activity. In addition, we provide a small overview on modeling formalism to justify the choice of UML as a base line.

Model-based engineering in the context of real-time embedded systems where tool support for guaranteeing functional and non functional properties is an important issue, is possible nowadays for specific applications, using tool supported approaches like the B method [Abrial] or the synchronous approach implemented in development environments like Scade [Scade], Esterel [Est] or Signal-RT Builder [RTBuild]. However, these approaches are nowadays applicable only for quite specific platform architectures, and they are based on a global rather than a compositional approach. There is ongoing work on this issue also within Artist, for example in the activity on “Merging the time and event triggered paradigms” where a quite complete overview on the state-of-the-art is given.

Component-based engineering is widely used in circuit design, supported by a large number of tools. In software and system development, component-based techniques have been introduced, based on object technologies supported by standards such as UML and CORBA. However, these techniques have not yet achieved the same level of maturity as has been the case for hardware and their relevance to embedded systems is growing but still limited, mainly as there exists only limited support for guaranteeing any non functional properties of the systems based on these frameworks.

Current state-of-the-art concerning component-based engineering is characterized by the following challenges to the development of complex embedded systems:

- Most frameworks lack rigorous semantic foundation. They do not support precise meaning for component and sub-systems composition. Recent developments on frameworks for heterogeneous systems are detailed in the activity report on component modeling and composition. There exist some tools aimed at giving an operational semantic basis to modeling frameworks, such as Metropolis [BWHL03] and IF [BFG*99, BGOO04]. Some existing tool support for model-transformation is aimed to filling this gap [KSL*03, KMFD*05].
- Most frameworks ignore or fail to encompass description of timing and resource management aspects which are essential for non functional behaviour. Commercial tools for UML or AADL offer mainly syntactic sugar for time and scheduling policies. This drastically limits the possibility of formal analysis before an actual implementation and deployment is ready. There exist tools for schedulability analysis based of rate monotonic tasks [LL73] and some extensions, and there exists tools implementing a simulation approach. Such tools will be part of the platform (e.g. [GMG*02, MFHS05]). What is missing so far is a better connection between the model used for timing analysis (where “components” are related to the run-time architecture, that is tasks, physical distribution and communication) and the functional design model (in which components are more related to functional decomposition). Some tools have been proposed for combined analysis of design models and architecture models, either back-annotating design models

with architecture information [CPP*01] or by joining design models with architecture models [BWHL03, OGOL05a] and to some extent also the work in [HA*04].

The platform will be based on some of the most advanced tools and will directly profit of the progresses achieved in the action on component modeling and composition and the advances on integrating the missing aspects in UML.

Concerning existing analysis techniques for non functional and QoS properties, a large number of academic and also commercial tools --- in particular concerning performance and schedulability analysis, so that it is not possible to give a complete overview (an overview on state-of-the-art analysis techniques is given by the validation and testing cluster).

A major issue with analysis is scalability. State-of-the-art techniques can validate detailed designs of small (sub)systems, but only very abstract models of real systems. There exist well understood compositional approaches, which need to be supported by tools and the modeling framework, e.g. the assume-guarantee techniques introduced recently in [AH01]. Abstraction techniques [CC77, GS97] are integrated only in few validation frameworks, e.g. Slam [BR_2002] or Bandera [HD*02] to verify complex software.

But the main effort needed with respect to analysis is achieving an appropriate integration with development tools and methods. We are aiming a more open and less specific environment than those based on the synchronous approach cited above, by nevertheless integrating their achievements. This will be made easier by two current developments: First, one of the aims of the MARTE profile is to provide some means to make UML compatible with the synchronous approach which is not the case in UML 2.0, and even more importantly, tool vendors, such as Esterel Technologies, started already to connect their tools to UML for importing both architecture specifications and high level functional specifications of components.

The general acceptance of UML together with the tendency mentioned above justifies in our opinion the choice of UML as a baseline. Moreover, UML in its present version has profited a lot from a number of modeling notations, such as the ROOM notation, SDL, State Charts, Live Sequence Charts and AADL.

A more detailed historical account on UML is given in the report of the activity on "*Developing UML for Real-time embedded systems*". A directly relevant work at OMG concerning this platform is a recently started initiative for a semantic framework. Nevertheless, from intermediate results, recently presented at a workshop [ECMDA05], the usefulness of this work for the purpose of tool integration is still unclear. If we can progress on the semantic platform and provide convincing results in time, we might be able to provide some input to this profile.

Partner's background tools on which the platform is being built

The partners participating in this activity have a long lasting experience in building tools that have been used for realistic case studies in several projects. In this section, the main characteristics of these background tools are given. In the section on ongoing work (4.3) more information is provided how these tools and the ongoing work contribute to the platform.

1. *Verimag*
    a. Has developed the IF a simulation and verification platform for real-time systems. This platform has been initially built for validating SDL specifications, but also for providing a semantic platform for model exchange amongst tools and for being open to other user level formalisms [BFG*99]. In the Omega project, a front-end for the OMEGA UML profile [DJPV05, GOO05] with real-time has been provided [BGOO04]. This tool plays a major role in many collaborative projects and has been used in many realistic case studies.

b. Has developed the Hermes tool [BLP03], dedicated to the verification of secrecy properties of cryptographic protocols in a fully automated fashion by considering an unbounded number of sessions, participants and nounces as well as potentially unbounded message sizes. It has been used successfully on a large number of protocols

2. *IRISA*

   a. Has developed UMLAUT [HJPP02], a framework for building tools dedicated to manipulating models described in UML. It has been used to generate validation models and to weave multi-viewpoint UML models into code.

   b. Has started to develop Kermeta [MFJ05, MFD*05], a generic language and tool for model transformations, model simulation and prototyping.

3. *CEA*

   a. Has designed its Accord/UML workbench as pluggins in the context of the Eclipse platform. All Accord eclipse pluggins have been integrated in the Rationale-IBM UML2 tool called RSA. The Accord/UML workbench provides specific UML2 profiles in order to specify and prototype (including specific code generation) real-time embedded systems.

   b. Has continued to design its Accord execution platform designed in C++ and available on Linux and VxWorks. This platform support the multi-tasking execution of the code generated from the RT/E application model designed with the Accord/UML methodology using the previous described workbench.

   c. Has developed a gateway (model transformation) towards the Agatha tool (a formal symbolic execution tool provided also by CEA) in order to perform schedulablity analysis on UML models. This connection ensures also to generate automatically test cases.

4. *The Uppsala team* has developed the TIMES tool [HMPY04] for schedulability analysis and code generation, guaranteeing timing constraints. TIMES has been used to analyze and identify performance bottlenecks in a control system for industrial robotics.

5. *OFFIS* has developed a UML validation toolset UVE supports validation of safety and liveness properties of UML design adhering to the OMEGA profile [DJPV05]. Properties may be expressed using a subset of temporal logic or by means of Live Sequence Charts [STMW04, DW05]. The tool can also be used for compositional verifications where the omitted environment is specified by properties (assumptions). To analysis non-functional constraints OFFIS has developed a tool for timing analysis and scheduling of distributed systems [MFHS05] as well as an innovative tool to perform model-based safety analysis - as for example fault tree analysis, or common cause analysis - using formal verification techniques [PBB*04]. It is an ongoing activity to extend these techniques and to incorporate these techniques in an UML component-based approach.

6. *PARADES* has developed Metropolis [BWHL03], a tool-set for integration of heterogeneous model of computations and checking of functional and non functional properties.

7. *U. of Cantabria and UPM* have developed the MAST tool [GMG*02] which is an open source set of tools that enables modeling real-time applications and performing timing analysis of those applications. The MAST model can be used in a UML design environment to design real-time applications, representing all the real-time behavior and

requirements together with the design information, and allowing an automatic schedulability analysis.

8. *U. of Dortmund* has developed jETI [Mar04], a further evolution of the ETI platform [SM97]. The main functionalities of this platform is to allow to build transparently for the user complex functionalities from basic functionalities provided by a set of distributed tool servers from high level (constraint based) specifications.
9. *INRIA (SARDE proj.), FTRD and ST Microelectronics* develop since several years THINK [FSLM02], a new approach for developing versatile component based OS, driven by an architectural view of the system to design, supported by the adherence to Fractal [BCS02], an open and extensible component model with execution platforms and tools (configuration, management, etc.) in different languages and targeting several middlewares. THINK allows native component connection by means of a dedicated ADL (Architecture Description Language). We have recently published a new tool release together with a new component library targeted on ARM platform. All this software is published under (L)GPL license on the objectWeb site (http://www.objectweb.org).

4.2 Industrial Needs and Experience

European automotive and aeronautics industries are experiencing an exponential growth in functionality, with a drastic increase of innovations realized in software. The paradigm is shifting from an original “1 function = 1 ECU = 1 supplier” partitioning to distributed realizations of functions across multiple ECU’s involving multiple suppliers.

Several de-facto standards such as CAN, Flexray and the various OSEK extensions have found there way into series development. Model based development is increasingly gaining momentum, often involving automatic code generation.

However, system-oriented design and virtual integration with early analysis of functional and non-functional properties are supported only weakly, leading to late detection of integration problems. Late requirement changes, incomplete initial requirements, or even inconsistent requirements are often leading to late design iterations or changes, with high incurred costs.

In the context of telecommunication infrastructure and services, components play and have played a crucial role. The majority of these components are embedded in core network platforms or several types of devices (e.g., mobile and fixed). Components may be shared between different applications. Today, real-time and QoS requirements, which are essential for service deployment and provision, cannot be analyzed during the early stages of design, as QoS properties are well studied and expressed only at a very low level. Abstract Service level models cannot be compared to the actual design models.

In all domains two essential needs emerge for which appropriate modeling frameworks and platforms must be developed. One is an appropriate modeling framework supporting components-based design, decoupling of functional design from platform and distribution and consideration of non-functional and QoS characteristics on high-level models. Another is to exploit such a modeling framework by providing tools for system level analysis of non-functional and QoS properties from an early design stage on, and through the entire development cycle, and beyond.

4.3 Ongoing Work in the Partner Institutions

Ongoing work concerns tool support for modeling frameworks, tool integration frameworks and of model transformation and some analysis building blocks concerning particular analysis

techniques. Most of the activities are carried out by groups of partners and share effort with other cooperative projects at National or at European level.

All the following lines of work consider one of the following three issues which are needed for the realization of the platform:

- Semantic level validation platforms
- model transformation or analysis tools
- or specific work for one of the identified tool-chains:
    - A platform for the development of safety-critical embedded systems
    - A platform for the analysis of performance critical service-based systems
    - A platform for the certification of smart-card applications.

Bibliographic references refer to the clusters publication list at the end of the report.

There are five main ongoing activities concerning semantic level platforms.

- The MARTE UML profile [EDG*05] for modeling component based real-time systems and their non functional properties, plays a central role as an exchange format for models. Within the CARROLL research program (between CEA, INRIA and Thales), the Protes project is aiming at defining the OMG standard meta-model and its related UML profile for modeling and analysis of RT/E systems. Implementation of the support platform is scheduled to start in 2006.

  This work is a basis for the UML profiles considered in the platform. The development of the profile is mainly relevant for the activity on "*Developing UML for Real-time embedded systems*". The implementation of the profile is part of the platform activity

- The IF tool [BGOO04] for the modeling and the analysis of distributed real-time systems and the experience gained in modeling and validation [GOO05, OGOL05, OGOL05a, OGY05, HAB*05] can play an important role for semantic level model exchange through its separation of behavior, interaction and coordination. It is connected to the OMEGA UML profile (this has been done in the OMEGA project).

  This year, we have worked on a new version of IF, which takes better into account the notion of component and offers a richer interaction model and which is based on a component framework [GS04,GS05] with well defined properties that can be used for analytical or proof based approaches. This extended version is called IF/BIP.

  The work started on the extension of IF, is an important basis for the semantic level format. It will be used to connect the MARTES and SPEEDS profile to existing IF state space exploration tools. Moreover, we expect at a later time to be able to analyze models built using several modeling tools by means of a semantic level integration of models. The IF/BIP tool will be used in all three platforms

- The Metropolis framework [BWHL03] has been built with a similar aim and structure and will conceptually play a similar role to IF, by providing access to additional backend tools. It also separates well the aspects of behavior, interaction, coordination and non functional properties using a semantically rigorous meta-model for capturing heterogeneous components at the same or different levels of abstraction. It accepts operational and denotational specifications that are expressed as constraints on the behavior or on non functional properties. Metropolis uses a first order logic, Logic Of Constraints LOC), for specifying the denotational aspects. The methodology it supports, called Platform-Based Design, is also used to map functionality onto an architecture that may be hardware or software. Functionality and architecture are kept separate while mapping is analyzed, thus offering a method for design space exploration that does not require continuous modification of the design representation. Non functional properties, e.g., timing, size,

power, and cost, are associated to the behavioral model via quantities that can be either used as arguments of LOC or back annotated for simulation. Metropolis can be used for faithfully simulating systems of heterogeneous components and is connected to back-end validation tools, such as SPIN [Hol04] and Prometheus [Gos01] for timing verification and tools for refinement checking. The framework accepts as inputs different formalisms including UML that has been used to design wireless sensor networks in Metropolis.

The Metropolis tool will be connected to the platform for safety critical systems.

- The Kermeta language and tool for model transformation [MFJ05, MFD*05, RFG05] is Eclipse-based. This framework is already used today within the INRIA team support a component based software design process.

  The Kermeta tool will play a key role in providing model transformation technology. Within the platform activities, the Inria team is working on the integration of IF based concepts into a mainly UML based component model.

In the contexts of the projects OpenEmBeDD and SPEEDS, the above mentioned approaches for tool integration will be adapted to the modeling frameworks considered in the individual projects. One objective is to reach compatibility at the semantic level.

- jETI [MNS05, MNS05a, MRS05], a redesign of the Electronic Tools Integration platform (ETI) is envisaged as a tool for the integration of individual analysis and transformation components into complex functionalities. It contains high-level coordination facilities, including graphical ones, and accumulates over seven years of experience.

  An important issue addressed is the reduction of the effort for integrating and updating tools. jETI combines Eclipse and Web Services functionalities and support for distributed execution. These features will allow making the platform tools ARTIST-wide available or even public. However, we consider these features not as critical for the project but rather as a nice-to-have add-on. This type of integration will not start immediately.

The following lines of work are related to particular modeling and application frameworks

- The aim of the recently started French Persiform project (with Artist partners FTRD, INRIA and Verimag) is the integration of performance evaluation into the design flow. A first aim is to connect commercial performance analysis tool (event-based simulation mainly) to functional UML modeling tools for high-level performance analysis, in particular service specifications expressed in terms of activity diagrams, and possibly sequence diagrams. For this purpose, a profile for the use of activity diagrams has been defined and given a formal semantics. Based on this semantics, transformations into performance models and into IF models are defined, where the IF tool is used for validating non probabilistic properties, such as deadlocks.

  In a second phase, also design specifications with performance annotations, compatible with the MARTE profile, will be transformed into IF models for validation and into performance models for fine grained performance analysis. Also consistency checks between service and design level models will be implemented.

  The work done in the Persiform project provides the kernel of the second platform for performance critical, service oriented systems. For the design level specifications, (to be considered at a later point of time) we hope to be able to reuse the work done on the profile for the first platform.

- This year, VERIMAG, INRIA and FTRD have started a joint project to extend the THINK architectural view with a dynamic view. It will be enforced by an ADL extension and rely on formal models of the behavioral point of view (using the Kell calculus from INRIA SARDE)

and the timely point of view (using IF or related model from VERIMAG). Targeted Systems are principally safety critical ones with hard real time constraints, but performance oriented systems are also addressed. This project will be partially supported by the regional EMSOC project.

This work will be useful for the integration of dynamic architecture descriptions. They are likely to be less useful for platform 1, but very useful for platform 2. We expect to have results in the third year.

- In the Swedish Save project, partners from Malardalen (MdH) and Uppsala collaborate in building predictable assembly of components used in SaveCom component model (SaveCCM). The SaveCCM software component technology [HA*04] is intended for embedded control applications in vehicular systems. In SaveCCM flexibility is limited to facilitate predictable assembly of vehicular applications. Important attributes in the domain are safety, reliability, and timeliness.

  The tools developed provide (1) support for high level modeling and expression of high-level constraints, (2) support for generating code for the targeted run-time system (3) and extraction of specialized analysis models targeted for analysis tools like Uppaal, Times [HMPY04] or others. Successful applications are described in [TFC05, AM*05].

  The Times tool is further developed in the context of the Swedish ASTEC project. It allows translating UML Rhapsody diagrams with SPT annotations into TIMES models [FMPY05]. The goal is to use TIMES for schedulability analysis of UML models and code generation. The work has been conducted in collaboration with I-Logix. A prototype virtual machine (named TICK) for timely execution of automata-based component models is currently under development. On top of the kernel, component models may be developed, compiled, simulated and executed symbolically.

  The experience with the SaveCCM will be interesting for the definition of the profile for the first platform. The connection of the framework to the platform is presently not planned. The Times tool will provide a backend validation engine

- The aim of the MAST environment is to provide schedulability and simulation analysis models and open tools including support for UML-based development, where the target is the MARTE profile. Presently developed functionalities are the generation of target code analysis models from UML complementary models and a mapping on a target architecture description, as well as state-of-the-art tools for schedulability analysis.

  The MAST tool will provide a backend validation tool that will implement most of the specific timing annotations defined in the MARTE profile.

- The ITEA FAMILIES project was concerned with product line modeling. In this context, a common meta-model for variability has been defined and may be applied to component models. Moreover, a first draft of a QoS-aware component model has been defined. Particular kinds of real-time QoS have been investigated and a link between such annotated model and schedulability analysis techniques been developed. This important issue is mostly orthogonal to the other issues considered. We hope that the results of this project can be combined with other frameworks, if needed.

  The work done in this project will not be directly integrated into the platform. But the experience gained in this project will influence the MARTE profile and is also potentially useful for the platform 2.

- The French EDEN and EDEN 2 projects (with Artist partners CEA and Verimag) is concerned with formal validation of smart card application with respect to common criteria. It is based on 3 layer development methodology, where the project is mainly concerned with the upper layers (requirements – consisting of security properties, and high-level

design) defined by Trusted Logics and implemented in their tool TL-FIT. In a first phase, security properties have been expressed using IF observers and validated using the IF tools. The aim of a second phase is a UML profile targeted for the expression of high-level security requirements.

The work done in the EDEN project will provide the kernel of the third platform for Java card applications. The profile for the expression of security properties may also be useful in the context of safety critical systems.

Most of the previously mentioned settings include also back-end analysis and/or model transformation tools, which can be made available as independent analysis components that can be used in several contexts.

The work on the platforms 2 and 3 is already progressing well. The start of the projects SPEEDS and OpenEmBeDD and the first version of the MARTE profile will allow starting the work on platform 1 as well.

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