Modeling of Real-time Embedded Execution Platforms

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1. Introduction

The increasing complexity of systems especially in the real-time embedded domain has introduced new challenges for researchers to look for new approaches and methods for the design and development of such systems. Component-based development method by providing a higher degree of reuse in the system is helpful in reducing the cost and risks in the development of the systems. On the other hand, model-driven engineering aims to raise the level of abstraction in the development of systems and also introduce reuse in terms of development patterns. It also offers separation of concern through different views/models in the system. The MDA approach for model-driven engineering proposed by OMG, for example, separates the business and application logic from the underlying platform technology by using Platform Independent Models (PIM) and Platform Specific Models (PSM) [1]. Thus, model-driven engineering is very helpful for the design of complex systems. Therefore, combining this approach with component-based development seems very promising to manage the complexity of real-time embedded systems. However, it also introduces new challenges: “1) to develop components that can be certified individually for provably guaranteed delivery of the required level of service in operation; 2) to preserve those guarantees in an assembly of heterogeneous software components on the target execution platform” [2]. This is the scope of CHESS project and its goal is to come up with model-driven solutions to solve the problem of property-preserving component assemblies for the design of embedded real-time systems to ensure consistency of non-functional properties at design and execution levels. This also helps to perform analysis of the system in earlier phases of development.

There are several industrial domains involved in CHESS project such as railway, telecommunication, space and automotive. The outcome of CHESS project should be solutions with industry qualities and specifically applicable in these domains. The Swedish partners, which are more active in the telecommunication domain, in CHESS project are: Ericsson AB, Enea AB, and Mälardalen University.

1.1 My Role in the Project

Enea AB company provides software systems, tools and services for high-availability mission critical embedded systems1. Its flagship real-time operating system is called OSE which comes in several versions targeting different complex distributed systems such as multi-core and DSP-based systems. Recently Enea has also started offering its own Embedded Linux distribution as well.

As a representative of the company in the project, my tasks will be more focused on providing and adapting the execution platform for the requirements of CHESS. In other words, it will be about the runtime features in the execution platform that provide for property-preservation features in

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1 Enea AB: http://www.enea.com/
CHESS, and the link between the models to this property-preserving runtime environment. Thus it includes topics such as transformations and modeling of the execution platform resources and services.

2. Research Methods and Issues
This project involves both academic and big industrial partners. So the solutions need to go beyond theoretical level and should be something practical and applicable for the industrial partners in the project. On the other hand, the industrial partners also suggest the tools and technologies that ought to be used as part of the solution. This close collaboration with industry has both benefits and challenges. The benefits are that it is possible to get a clearer picture about the interests and needs of the industry and also gain a good knowledge about current technologies used in industry. All this also prevents the final results of the project from being too theoretical in the end and not applicable in the field. The challenge it brings is the need to also investigate and learn about some of the tools that different industrial partners use now or plan to use as part of the final solution. This requires studying different reference manuals and books besides papers, theses and so on.

Based on what mentioned above, the research approach in this project is somewhat tricky in the sense that it requires a good balance between studying features of industrial tools and available academic literature, methods and approaches plus meeting with both industrial and academic partners to gather their requirements and expectations.

3. Related work and Literature
One of the main objectives in the project is to define a UML profile called CHESS which includes the semantics necessary for modeling of real-time embedded systems with the focus on railway, telecommunication, space and automotive domains. The CHESS profile should contain elements and semantics which not only enable modeling of such systems but also can be used to perform analysis of the designed system. This requires mechanisms in the profile to decorate the model elements with non-functional properties.

Two of profiles offered by OMG that cover different aspects in modeling of real-time embedded systems are: UML Profile for Schedulability, Performance and Time (SPT) and UML for Modeling Quality of Service and Fault Tolerance Characteristics and Mechanisms (QoS&FT) (For more information on these two profiles you can refer to [3] and [4]). However, as discussed in [5], these profiles have limitations in defining non-functional properties flexibly and representing the concept of time. So there was a call for proposal of a new profile in this domain which resulted in the introduction of UML profile for MARTE which is short for Modeling and Analysis of Real-Time Embedded Systems.
By investigating different MARTE packages, it is now decided that the concepts in MARTE are appropriate for the scope of CHESS project and can be tailored to serve as the basis for the CHESS profile. A brief introduction to this profile is offered in the following section.

3.1 MARTE

UML profile for MARTE (Modeling and Analysis of Real-time and Embedded Systems) was introduced to replace the UML profile for Schedulability, Performance and Time (SPT). It includes concepts and semantic for a model-based descriptions of real-time and embedded systems. The core concepts in MARTE are categorized in two parts: modeling and analysis. The intent in the analysis part is not to define new techniques, but to provide a framework to annotate models with the necessary information in order to support different kinds of analyses in the real-time domain, particularly performance and schedulability. Figure 1 shows the dependency of MARTE on other OMG standards.

![Figure 1: MARTE and other OMG standards [6]](image)

One of the main characteristics of MARTE is that it provides a common way to model both the hardware and software aspects of real-time systems. This improves the communication between developers and helps to include both hardware and software characteristics in making predication and analysis of the systems.

There are several basic principles considered in introducing MARTE specifications which are as follows [6]:

- It should support independent modeling of hardware and software parts of a real-time embedded system and also the relationships between these parts.
- The profile should provide both high-level and low-level modeling constructs covering phases from specification to implementation.
- The profile should not limit modelers in choosing the style and modeling constructs that they think are most appropriate to represent and fulfill the needs of their systems. In other words, in order to enable model analysis, the profile should not enforce a specific approach and style.
Modelers should be able to go for any different analysis techniques without the need to have a deep understanding of those techniques.

While supporting all major current real-time technologies, design paradigms and model analysis techniques, the profile should also remain open to new methods and techniques.

“It must foster construction of UML models that can be used to make quantitative and partitioning predictions and analysis regarding hardware and software characteristics of the RT/E system. In particular, it is important to be able to perform such analyses early in the development cycle. For that, it has to be possible to analyze partial models. It should be possible to automatically construct different analysis-specific models directly from a given UML model. Such tools should be able to read the model, process it, and feed the results back to the modeler in terms of the original UML model” [6]

The semantics in MARTE are classified into several sub-packages. The structure of these packages in the MARTE architecture is shown in figure 2.

Figure 2: MARTE architecture and packages [6]

3.2 Resource Modeling
Since I need to focus more on the parts of the project related to execution platforms, investigating resource modeling packages in MARTE was a part of my tasks in the technology investigation phase of the project.

MARTE offers a comprehensive collection of semantics to model resources and services of the execution platform at different detail levels. The core concepts are gathered in the Generic Resource Modeling package (GRM). Besides GRM, there are also Software Resource Modeling (SRM) and Hardware Resource Modeling (HRM) which make use of the concepts and definitions in GRM package. GRM contains definitions for basic resources in the systems such as ComputingResource (CPU or any unit capable of executing program code), CommunicationResource (to model communication endpoints and communication media, e.g. could be an Ethernet network and network cards) and so on. SRM package, on the other hand, offers semantics to model multi-tasking features of the systems in more detail. Modeling concurrency, synchronization, schedulable resources (such as tasks) and interrupts are in the scope of this package. Finally, HRM package offers the necessary semantics to model the logical and physical aspects of the hardware part of the system. Devices and entities such as hard disks, RAM, ROM, CACHE, I/O, etc. are modeled using the concepts offered in this package. The physical characteristics of the hardware such as placement, shape, power consumption and so on are taken care of by the HW_Physical sub-package of HRM package. For more information on MARTE resource modeling packages refer to [6] and [7].

3.3 Other Related Areas
Besides model-driven engineering, other areas that I also need to work on to fulfill my tasks in the project include studying features of real-time embedded operating systems such as OSE and Carrier Grade Linux [8] (Linux tailored in terms of availability, scalability, manageability,... for use in telecommunication domain) and some other necessary topics in real-time embedded field. I would need to cover parts from all these areas and use them together to be able to perform my role in the project. So different literatures I may need to use range from UML (profiles, profiling features...), Model-driven engineering to embedded Linux, OSE and other technical texts and manuals.

4. Research Groups and Conferences
* Innovative Centre for Embedded Systems (ICES)
ICES focuses on cooperative multidisciplinary research with special emphasis on system design, architecting and methodology; areas where theories, their application and tools have not been able to keep up with the technology evolution. ICES will provide a platform for cooperative research, education and innovation [9].

This Swedish-established conference and its related workshops, although still young, are relevant and useful for my subject especially that many industrial partners such as ABB, Scania, ÅF... besides professors and lecturers from KTH and some other universities participate and present their recent research achievements and current issues in the field.
* Institut de Recherche en Informatique et Systèmes Aléatoires (IRISA)
  Created in 1975, is a joint research unit (UMR 6074), including CNRS, University of Rennes 1 (main establishment), INSA Rennes and ENS Cachan (Brittany site) all being signatory establishments for the 2008-2011 new contractualisation [10].

They have a strong and active MDE research team and have developed products such as KerMeta which is a “powerful metaprogramming environment based on an object-oriented DSL (Domain Specific Language) optimized for metamodel engineering” [11].

* MODELS (ACM/IEEE International Conference on Model Driven Engineering Languages and Systems)
  The MODELS series of conferences is devoted to the topic of model-driven engineering, covering both languages and systems used to create complex systems. These conferences are both an expansion and a re-direction of previous Unified Modeling Language (UML) conferences. The MODELS series replaced the UML series in 2005 [12].

* International Conference on Model Transformation (ICMT)
  International Conference on Model Transformation [13].

* Different Training Workshops and Crash Courses at Enea
  Enea holds several training workshops per year focusing on practical topics such as embedded Linux, OSE RTOS and designing real-time systems with OSE and so on [14].

* MoDeVVA (Model Driven Engineering, Verification and Validation)
  “The objective of the workshop on model-driven engineering, verification and validation (MoDeVVa) in 2009 is to offer a forum for researchers and practitioners who are working on V&V and MDE. The main goals of the workshop are to identify the mutual impact of MDE and V&V: How can MDE improve V&V and how can V&V leverage the techniques around MDE?” [15].
References


[8] Carrier Grade Linux: http://www.linuxfoundation.org/collaborate/workgroups/cgl


