IST-004527 ARTIST2
Network of Excellence
on Embedded Systems Design

Activity Progress Report for Year 4

JPRA-NoE Integration

QoS Aware Components

Clusters:

Adaptive Real-Time

Real-Time Components

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Policy Objective (abstract)

QoS management is one important concern in the design of real-time systems. Component-based technology is a relevant approach to complex system development and to allow a smooth integration of software from different vendors. QoS management is an adequate mean to provide a predictable quality to end-users. The goal of this activity is to bring together competencies in component-based design for hard and adaptive real-time systems, to produce advances that would be difficult to achieve otherwise.

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1. Overview of the Activity

1.1 ARTIST Participants and Roles

Alejandro Alonso (UPM): QoS component infrastructures and notations for QoS specification.

Jean-Marc Jezequel (INRIA): extra-functional modelling.

François Terrier (CEA): QoS information in models.

Jacques Pulou (FTR&D): QoS in component-based middleware.

1.2 Affiliated Participants and Roles

Laurent Pautet (ENST): real-time middleware, timed contract based behavioural typing, component-based adaptive services in mobile networks.

Stefan van Baelen (K.U. Leuven): QoS specifications and negotiation mechanisms.

Marisol García-Valls (U. Carlos III of Madrid): QoS component infrastructures, real-time middleware architectures.

Virginie Watine (Thales): component-based middleware, Co-Chair of MARS group at OMG on CORBA, RTE, etc.

1.3 Starting Date, and Expected Ending Date

Starting date: December 1st, 2004.

Ending date: End of the project.

1.4 Baseline

QoS concepts are starting to appear in component standards, but are far from mature. Partners in this JPRA have expertise in different aspects necessary for progress. An example is the request for proposal at the Object Management Group that is currently demanding solutions for the integration of some QoS facilities in CORBA Component Model.

There are a number of techniques and methods required for the industrial use of QoS aware components such as:

- Notations for the description of components models including functional and QoS (also know as non-functional) aspects. The integration of this information in the interfaces is of primary importance.
- Automatic generation of analysable models from the UML model.
- Composition mechanisms for determining whether the interconnection of two components is feasible and for deriving the non-functional characteristics of a group of connected components. This work is related with the adaptation of component execution to changes in the environment.
- Component frameworks to support the runtime composition of QoS aware components.

1.5 Problem Tackled in Year 4

The work in year 3 has continued with the main research topics dealt in previous years. The partners have continued with their efforts towards the development of notations for integrating the description of non-functional or QoS properties in pure functional models. In this way is possible to assess whether a certain design meets a number of non-functional requirements. In particular, the work on safety systems has continued with a number of improvements and writing of journal papers for the dissemination of results. The contribution on OMG standards has also continued during this period of time. The revision on the standard on the "*UML Profile for QoS and Fault Tolerance*" nearly finished last period, so few work has been performed on relation with this. The efforts on the "*UML Profile for Modelling and Analysis of Real Time and Embedded Systems*" (MARTE) try to consolidate this standard, in order to fully align it with others and to deal with some comments. The partners are also contributing to the OMG standard on "*MDA Tool Component RFP"* Finally, some work has been devoted to complete a reference implementation for the resource and quality management in the ISO/IEC 23004 standard, which is specially suited for embedded systems.

The automatic generation of models for analyzing a particular characteristic is one of the major advantages of modelling together the system functional behaviour and QoS. During the last year some of the theoretical results obtained have been used on research projects to improve the development of systems meeting QoS requirements. In particular, support for the following properties have been developed: fault-tolerance, adaptability, time, and safety.

The definition of the composition of QoS aware components is another subject of research. UML extensions have been developed in order to define adaptable elements and dealing with the composition problem by the integration of search algorithms.

1.6 Comments From Year 3 Review

1.6.1 Reviewers' Comments

The document clearly exposes the work achieved in year 3, the role of each partner, the standardisation activities and the future work for year 4. Partners should put more effort on dissemination besides OMG related activities. The link between the activities of the partners is not very clear. It appears like a set of independent activities around QoS and components than an integrated cooperation. Relationship with other clusters is also not evident besides the common background on component with RTC cluster.

1.6.2 How These Have Been Addressed

Dissemination of the work performed in this activity has been carried out by publishing some mature results in journals, publications in workshops, active contribution in OMG standards, and technology transfer. Some of the outcomes of this activity are being used in research projects.

Partners in this activity have collaborated with external partners to the activity, such as the University of Aveiro, University of Dortmund, Evidence, Universidad Politécnica de Valencia and Universidad de Cantabria. The strongest relation is still with cluster RTC, as was established in the project proposal. The interaction between partners is being carried out by collaboration in common projects, and collaboration in OMG standards, and meetings in workshops on topics related with the activity.

2. Summary of Activity Progress

2.1 Previous Work in Year 1

Some partners cooperated in the development of the OMG standard “UML profile for QoS and Fault Tolerance”, which was finally approved on May 2005.

The main result of this work was the concrete identification of the more concrete integration topics and the start of this work. This final job was done during a meeting that allowed the partners to know each other and discuss their interests. The identified integration topics were:

- Consistent alignment between the QoS modelling style of MARTE (with basis on Schedulability, Performance and Time) and that of the UML Profile for QoS and Fault Tolerance. The fist one is mainly related to time and performance aspects, while the second is more general, as it tries to provide means for specifying any other QoS characteristic. Partners involved: CEA, Inria, UPM.
- With respect to composability, the interest is focused upon the development of a contract model with well-founded semantics with respect to time and execution. This contract model handles (some) QoS characteristics. Partners involved: CEA, Inria, UC3M, UPM
- Finally, the support for the execution of QoS aware components requires components infrastructures with this support. UPM (QoS in the Robocop framework), UC3M, CEA and Thales (CCM based extensions) have done previous work on this topic. They have also proposed containers to simplify components development. The goal will be to interchange the approaches to try to get their particular merits and to propose new concepts for their future evolution.

The work on these topics has started during the previous work period.

2.2 Previous Work in Year 2

The first issue was the identification of notations for the integrated description of functional and QoS properties in general component models. Some partners participating in this activity are active on two OMG standardization efforts that define such notations: OMG standards on UML profiles on “Real-Time and Embedded systems modelling and analysis (MARTE)” and “QoS and Fault Tolerance”. A complementary activity is the definition of catalogs of QoS attributes of a QoS characteristic, in order to try to develop techniques for their modelling. In the “QoS and Fault Tolerance” UML profile it is defined a general catalogue. In addition, QoS attributes for safety have been defined. An activity started during this period of time was the selection of a case study and QoS attributes, model them with different profiles or techniques and compare which is the most suitable in each case,

An important advantage of modelling QoS properties is the possibility of generating automatically models that can be used as input for analysis tools. The suitability of the previously mentioned profiles and attributes has been a subject of work for this year, with special focus on the QoS properties for timing and safety.

Another issue was to define the composition of QoS aware components. In this case, the connection of two components is only feasible if the provider includes the required operations with the proper functionality and QoS features. The common approach is the definition of a contract model where the specificities of the functions to be provided are determined and that

serves as the basis for the evaluation of the feasibility of the composition and the resulted quality.

There are components infrastructures that provide the required support for the execution of components. However, there are no mature infrastructures supporting QoS aware components. In addition to the general functions, support for the negotiation between components, for finding a suitable provider, and with the system, for getting the resources required for the system execution are needed. There are some initial works towards these goals; such as extensions to CCM by Thales and CEA and the QoS support at Robocop done by UPM.

2.3 Previous Work in Year 3

The work in year 3 has been mostly a continuation of the research topics of the previous year. The first issue was the identification of notations for the integrated description of functional and QoS properties in general component models, in order to reason about whether a component or a set of them fulfils a certain set of requirements. The integration of non-functional aspects allows for ensuring this property along the development lifecycle, hopefully, in an automatic way. Partners in this activity have continued their efforts in the standardization of this type of notations in the OMG (*Object Management Group*). The work on the "*UML Profile for QoS and Fault Tolerance*" standard has been subject of a revision considering a number of issues that were submitted by users. As a result, a new version of the standard has been approved on December 2006. The efforts on the "*UML Profile for Modelling and Analysis of Real Time and Embedded Systems*" (MARTE) have concluded with its adoption on June 2007 by the OMG. In addition, these profiles have been used to model safety and time.

The automatic generation of models for analyzing a particular characteristic is one of the major advantages of modelling together the system functional behaviour and QoS. Early evaluations of the system could guide to a better and cheaper end-product. It is intended to do them over the architectural designs; however, these designs are evolving until the architecture is completely specified. Automating such analyses in this changing environment is of great importance to aid engineers. Time and safety are the QoS characteristics that have been modelled in the context of this work. As a natural extension, the automatic generation of models for analysing them have been tackled.

The definition of the composition of QoS aware components has also been subject of research during this year. A UML profile for this job is under development. This work has naturally added a research topic: adaptability in QoS-aware systems. When composing a set of components, it is necessary not only to provide the required functions but the QoS characteristics as well, for setting the contracts. It is also required to determine which is the quality provided by this set as a whole. In addition, if these components can offer or require functions with different quality levels, it is of interest to know for each possible combination its feasibility and the overall provided quality. This information is relevant to statically evaluate the adaptability of a system and to change on runtime the provided quality according to the execution context.

The work on QoS management facilities in component infrastructures has been refined during this period of time. Additional functions have been added and a number of programming errors have been fixed. In addition, the API of the Robocop QoS Manager has been the basis for the specification of the resource and quality management in the ISO/IEC 23004 standard, which is specially suited for embedded systems. The integration of QoS in CCM also attempts to provide this type of runtime support.

2.4 Current Results

2.4.1 Technical Achievements

These achievements are aligned with the four main research lines:

a. Specification of QoS properties using UML profiles and aspect-based approaches
b. Generation of analysable models from the UML models
c. Composition of QoS-aware components and adaptability
d. QoS support in run-time components frameworks

For each technical achievement, there is an indication of the activity to which is mainly related.

Characterisation of services (UC3M, UPM, Aveiro) (a)

UC3M has developed a characterisation of QoS properties for service-based applications to enable functional composition in networked embedded systems. Contributions to the composition of applications in real-time have been made by developing algorithms that are able to make calculations with respect to selected parameters. This work has been done in collaboration with the University of Aveiro and UPM.

The solution for composing services-based applications developed by Uc3M is based on the definition of figures of merit, each one corresponding to a set of composition criteria, and the development of composition algorithms. The composition algorithms selects schedulable sets of implementations, while the figures of merit discriminates between different paths, in order to select the best according to a QoS criteria, e.g. minimization of utilization factor, minimization of the response time of the whole application, etc. On the other hand, UC3M developed two composition algorithms: an exhaustive one, suitable for off-line composition and an improved one, based on heuristics, suitable for on-line composition.

QoS in Component-Based Approaches (CEA LIST, THALES) (c)

Important results [1, 2, 3, 8] were obtained regarding *fault-tolerance* and *adaptability* in the **INFLEXION** project (Adaptable and Flexible Execution Infrastructure) from the "Usine Logicielle" program (SYSTEM@TIC PARIS-REGION Cluster). Replication can be achieved in a transparent way within a component-based approach. Replication is declared statically on model level and supported by middleware layer. It makes use of connector extension eC3M, www.eC3M.net.

In the context of **Flex-eWare** (French ANR project), CEA LIST defines a common meta-model for component aspects embedded and real-time applications, particularly oriented to UML-based models. Initially, CEA LIST carried out an empirical study that provides an intuitive description of composite structure semantics. Among practical solutions, a mechanism of encapsulating explicit behaviours in component ports has been proposed [4].

Consolidation of the MARTE standard (CEA LIST, Thales, UC)

One key standardization effort is the UML™ profile for Modeling and Analysis of Real Time and Embedded Systems (MARTE) at OMG. Currently, MARTE (http://www.omgmarte.org/Documents/Specifications/08-06-09.pdf) is in a second phase of the finalization tasks (version Beta 2) and is planned to be released in March 2009 (version 1.0). Regarding QoS and component-based support, some modelling features are being aligned to SysML and other related standards (AADL, Autosar, EAST-ADL, among others) [5]. At the

same time, a more precise semantics for VSL (Values Specification Language) is being provided. VSL is the expression language that is the basis to specify non-ambiguous non-functional aspects in MARTE.

CEA LIST is participating in a number of projects that are providing tool support for MARTE. Among them, FP7 INTERESTED, ANR Lambda and Usine Logicielle are specially interested in providing QoS modelling support in embedded systems development [7] [12] [6, 7]. Thales is collaborating with Thales in the context of this project.

Thales and Universidad de Cantabria have also participated in the standardization process of the MARTE standard.

Generation of Analyzable Models from the UML Models for Safety (UPM) (b)

Safety-critical software requires integrating verification techniques in software development methods. Software architectures must guarantee that developed systems will meet safety requirements and safety analyses are frequently used in the assessment. Safety engineers and software architects must reach a common understanding on an optimal architecture from both perspectives. Currently both groups of engineers apply different modelling techniques and languages: safety analysis models and software modelling languages.

UPM has developed solutions to integrate both domains coupling the mentioned types of notations. A model-driven development approach and the use of a platform independent language are used to bridge the gap between safety analysis (failure mode effects and criticality analysis and fault tree analysis) and software development languages (e.g. unified modelling language). Language abstract syntaxes (meta-models), profiles language mappings (model mappings) and language refinements, support the direct application of safety analysis to software architectures for the verification of safety requirements. Model consistency and the possibility of automation are among the main benefits. Safety annotations are included in the traditional software models and tools have been developed to automatically extract safety models that are a direct input to safety analysis tools. During the last year the previous work has been refined and extended with more rich safety modelling capabilities.

Task Force of "MDA Tool Component RFP" (MDATC) (UPM, Thales) (b)

In June 2006 the OMG raised a call for proposals for the standard: "MDA Tool Component RFP" (MDATC). Its goal is to create modelling tool support for defining a packing mechanism and interchange of development artefacts based on MDA, and to allow the reuse of development support tools based on MDA. This call can be found in: http://www.omg.org/docs/ad/06-06-09.pdf

UPM, along with a number of other companies and universities (Softeam, Thales, Universidad de York, France Telecom, and Adaptive) developed an initial proposal to meet the requirements of this standard call, which was presented on June 2007. (http://www.omg.org/docs/ad/07-06-12.pdf, http://www.omg.org/docs/ad/07-06-04.doc). UPM participated with more than a 50% of the original proposal, in particular, in the definition of the MDATC meta-model and a RAS (Reusable Assets Specification) profile.

OMG members studied this proposal and defined how to update the proposal. UPM is involved in the development of a reviewed proposal that was presented on September 2008 (http://www.omg.org/docs/ad/08-09-07.pdf). The group is currently developing a final version, taking as the basis the already presented proposal and comments from different reviewers. UPM is experimenting with this proposal for creating a package with the developed safety modelling tools, in order to facilitate the distribution of these tools.

Composition of Quality-Adaptable Components (UPM) (c)

Quality of service adaptability refers to the ability of components/services to adapt in run-time the quality exhibited. A composition study from a quality point of view would investigate how these adaptable elements could be combined to meet some system quality requirements and thus assess its feasibility. Enclosing quality properties with architectural models has been typically used to improve system understanding. Nevertheless these properties along with some supplementary information about quality adaptation would allow us to carry out a composition study during the design phase and even to predict some features of the adaptability behaviour of the system. Analogous supplementary information could be used to denote that several alternatives (e.g.: vendors, implementations) concerning quality can be used even when the system is not run-time adaptable, and a similar composition study would try to select the best choice. Existing modelling languages and tools lack enough mechanisms to cope with adaptability, e.g. to describe system elements that may offer/require several quality levels.

UPM has developed an approach that allows the reuse of existing modelling languages and tools, combine them and create new ones to tackle the problem of quality of service adaptability and composition: extending the standard UML profile for QoS to define adaptable elements, using the OCL language to define QoS functions, applying MDD transformations to process QoS metadata, adapting OCL tools to evaluate QoS expressions, solving the composition problem with search algorithms. The final goal of this work is to evaluate architectural models to predict system′s QoS behaviour before it is implemented.

QoS support in run-time components frameworks (UPM, UC3M) (d)

MPEG, a working group in ISO/IEC, is currently working in the standardization of an Application Programming Interface (API) for Multimedia Middleware (M3W), that as explained in the introduction, will allow application software to execute multimedia functions with a minimum knowledge of the inner workings of the multimedia middleware as well as to support a structured way of updating, upgrading and / or extending the multimedia middleware.

The Application Programming Interface mentioned above and a realization technology is specified in detail in ISO/IEC 23004 part 1-7. ISO/IEC 23004 part 8 is the reference software provided for this standard. Part 4 defines and API for resource and quality management. UPM has participated in this part since its beginning. The API provides the basic means to allow QoS-aware components to notify its quality information, to search for components providing a given quality and compose quality information. It is based on the HOLA-QoS quality management middleware.

This standard will include a reference implementation of this API to let final users experiment with the proposed API. UPM developed an initial version of a reference implementation for part 4 that includes a quality and a resource manager.

During the last reporting period, UPM has upgrading the previous version of the quality and resource manager initial version to make it compatible with a recent new version of a reference implementation of the components runtime environment and associated tools. In addition, it has been developed a set of components that encapsulate these managers and that allows for an easier modelling of the users QoS-aware components within this framework.

Rule-based approach to model adaptation policies (INRIA) (c)

In spite of new methods and technologies in software engineering such as CBSE, or AOP, it is still difficult to talk about adaptation since adaptation policies might impact the architecture, the configuration data, and some extra-functional features as well.

During 2008 the Inria team has finished the design of its QoS management platform. This platform uses a model driven engineering process where the designer can define adaptation policies for QoS properties of the system under design. The process and the tools rely on the metamodelisation of QoS properties, monitoring properties, adaptation policies, and simulations. The tools can also simulate the system to study the impact of changes in policies. A tool then generates monitors that supervise the running system to detect policy violations and activate adaptation behaviours. The work has been presented at the Embedded Real Time congress [5] at the French conference on Object Oriented Design LMO [4].

2.4.2 Individual Publications Resulting from these Achievements

[1] Javier F. Briones, Miguel Angel de Miguel, Alejandro Alonso, Juan Pedro Silva, “Quality of Service Composition and Adaptability base don Modeling Languages”, Submitted to ACM Transactions on Embedded Computing Systems. Special issue on Model-driven Embedded System Design, 2008

[2] Javier F. Briones, Miguel Angel de Miguel, Alejandro Alonso, Juan Pedro Silva, “Modeling Quality of Service Adaptability”, *AQuSerM: Advances in Quality of Service Management*, EDOC 2008 workshop, 18th September, 2008, München, Germany

[3] Javier F. Briones, Miguel Angel de Miguel, Juan Pedro Silva, Alejandro Alonso, “Integration of safety analysis in model-driven software development”, *IET Software*, ISSN 1751-8806, Volume 2, Issue 3. June 2008

[4] [Chauvel08a] Chauvel, F., Barais, O. and Plouzeau, N., "Expression qualitative de politiques d'adaptation", *Langages et Modèles à Objets* (in french), Montreal, Québec, march 2008

[5] [Chauvel08] Chauvel F., Borne I., Jézéquel J.-M. and Barais O., "A Model-Driven Process for Self-Adaptive Software", *4th European Congress ERTS Embedded Real-Time Software*, 2008. http://www.irisa.fr/triskell/publis/2008/Chauvel08b.pdf

[6] A. Cuccuru, S. Gérard and A. Radermacher, “Meaningful Composite Structures - On the Semantics of Ports in UML2”, *MoDELS*, LNCS 5301:828-842, 2008.

[7] Huascar Espinoza, Kai Richter, and Sébastien Gérar, “Evaluating MARTE in an Industry-Driven Environment: TIMMO's Challenges for AUTOSAR Timing Modeling”. *MARTE Workshop*, DATE 2008, 2008.

[8] I. Estévez-Ayres, Marisol García-Valls, Luís Almeida, and Pablo Basanta-Val. “Solutions for Supporting Composition of Service-Based Real-Time Applications”, *Proc. of the 11th IEEE International Symposium on Object/component/service-oriented Real-time distributed Computing*, ISORC 2008. May 5 - May 7, 2008. Orlando, Florida, USA

[9] B. Hamid, A. Radermacher, P. Vanuxeem, A. Lanusse and S. Gerard, “A fault-tolerance framework for distributed component systems”. *In Proceedings of the 34th Euromicro SEAA conference*, IEEE CS, pages 84-91, 2008.

[10] B. Hamid, A. Radermacher, A. Lanusse, C. Jouvray, S. Gerard and F. Terrier, “Designing fault-tolerant component based applications with a model driven approach”. *In IFIP Workshop on Software Technologies for Future Embedded and Ubiquitous Systems* (SEUS 2008), pages 9-20, 2008.

[11] B. Hamid, A. Lanusse, A.Radermacher and S. Gérard, “Designing Reconfigurable Component Systems with a Model Based Approach”, *In Workshop on Adaptive and Reconfigurable Embedded Systems*, APRES'08, 2008.

[12] Chokri Mraidha, Yann Tanguy, Christophe Jouvray, François Terrier, Sébastien Gérard “An Execution Framework for MARTE-based Models”, in *13th IEEE International Conference on Engineering of Complex Computer Systems proceedings*. IEEE, 2008.

[13] OMG, UML Profile for MARTE, http://www.omgmarte.org/Documents/Specifications/08-06-09.pdf, June 2008.

[14] OMG, MDA Tool Component (MDTAC), Current state of reviewed submission. http://www.omg.org/docs/ad/08-09-07.pdf

[15] OMG, MDA Tool Component (M[5]DTAC), Initial submission, June 2007, http://www.omg.org/docs/ad/07-06-04.doc

2.4.3 Interaction and Building Excellence between Partners

The interaction between the members of this activity has helped to enrich the different views and approaches of the research topics. The interaction has been made possible by partners meetings held in some of the workshops listed below and in the context of the OMG. A PhD student of UPM visited THALES for three months, in order to perform the modelling and analysis of the safety properties of the ATM architecture. There collaboration between partners in some projects, such as e-MAGERIT (UPM and UC3M) or Inflexion (THALES and CEA-LIST). Some students from UC3M have visited the University of Aveiro.

2.4.4 Joint Publications Resulting from these Achievements

The publication related with the characterisation of services based on QoS parameters has been resulted from a collaboration between the UC3M and University of Aveiro.

CEA-LIST, UPM and THALES have collaborated in the Task Force that produced the new version of the UML profile for QoS and Ft, in MARTE or in MDTAC standardization efforts.

UPM and UC3M have collaborated on the definition of the reference implementation of the ISO/IEC 23004 part 4, with respect to QoS and resource management.

2.4.5 Keynotes, Workshops, Tutorials

Papyrus Tool Suite: A Schedulability-Aware Execution Framework for MARTE-based Models, Tutorial at the MARTE Information Day, OMG Meeting, June 2008, Ottawa.

Presentation on Component-Based Approaches at COMES'08 ARTIST workshop (without publication): http://www.artist-embedded.org/artist/-COMES-08-.html

3. Milestones, and Future Evolution Beyond the NoE

3.1 Milestones

1. (achieved) Year 1: Identification of the concrete integration topics: modelling of QoS properties in design models and components frameworks.
2. (achieved) Year 2: Study and dissemination of the approaches from different partners. Definition of case studies for comparing the approaches and begin its modelling. The work has concentrated on UML profiles for the description of extra-functional properties and on evolutions of CCM and Robocop as the components frameworks.

   The partners have presented and distributed their recent work and view mainly on three topics: specification of QoS (extra-functional) properties, automatic generation of analysable models and run-time components frameworks. A case study has been proposed for the experimentation with these techniques. It is the simplified specification of a SCADA system. The modelling of functional and extra-functional properties with this case has already started. The information on CCM and Robocop frameworks has been distributed among the interested partners and their crossed analysis is under way.

3. (achieved) **Year 3: Completion of the use cases using the different modelling approaches. Comparison and identification of guidelines on their use. Refinement of the modelling of some specific QoS properties and automatic model generation.**

   Partners have continued with the development of UML profiles standards and have used them to model time and safety characteristics for some industrial and real use cases, such as the SCADA system. The automatic generation of analysis models have also been performed successfully for these cases. In addition, a profile for supporting QoS components composability is under development. This topic is a basis for dealing with adaptability to the context at design and run time.

4. (achieved) **Year 4**: **Propose a modelling technique that combines the best features of both for some selected extra-functional properties. Propose requirements for future QoS support on components framework. Develop prototypes for proving the validity of some of the new identified new features.**

   Partners have developed support for a number of QoS properties to be included in component models: time, safety, fault tolerance, and adaptability. In addition, some support has been developed for determining the global properties of the result of composing a number of components and for the generation of analysable models. The effort with respect to standard has continued, given the importance of this activity for the wide spread of this technology.

3.2 Indicators for Integration

This activity has strengthened the links between the communities of component-based development, adaptive middleware, and hard real-time, in order to create a momentum for developing technology for QoS in real-time systems. The interaction between partners can be shown by the following activities:

- Selection of a common example (SCADA) for exercising the notations and tools developed by UPM and CEA-LIST. This will help to compare and learn from the work of different partners, as the use case is known in detail.

- UPM and UC3M have collaborated in the reference implementation of the middleware complaint with ISO/IEC 23004 part 4. They have also collaborated in the e-Magerit project.
- CEA-List and Thales have collaborated in the project Inflexion.
- Cooperation between Thales, UPM and CEA-LIST in the OMG standardization efforts related with the UML profiles for QoS FT, and MARTE, and MDTAC.
- UPM is collaborating with University of Dortmund in the project MORE. Some of the achievements of these activities are being used in the context of this project.
- UPM, Universidad Politécnica de Valencia and Universidad de Cantabria have recently started a project call RT-MODEL that deals with QoS-Aware components, among other topics.

3.3 Main Funding

Main funding for UPM came from THREAD (Soporte integral para sistemas empotrados de tiempo real distribuidos y abiertos), which is a national research project. CICYT (Spain), Ref. TIC2005-08665, and from the RT-Model project. In this project, UPM is collaborating with the Universidad de Cantabria and Universidad Politécnica de Valencia. Some funding to UPM comes from the ITECBAN project.

e-MAGERIT: Research project of Comunidad de Madrid, SPAIN, (S-0505/TIC/0251). UPM and UC3M participate in this project.

Part of the work from CEA and THALES is funded with the French project Inflexion.

Funding for IRISA relies from the following projects:

- AOSD network of excellence (2005-2009)
- French national RNTL Faros research project 2006-2009, on contract-based component design and deployment.
- French national RNTL OpenEmb research project 2006-2009
- SPEEDS ITEA project 2006-2009

3.4 Future Evolution Beyond the Artist2 NoE

Support for QoS-aware components is an open research topic. Although, the work of the partners in this activity has resulted in a number of advances in the field, there is already a number of open issues, being the following some of the most relevant:

- *Extend the support to QoS properties*: This activity has dealt with four QoS properties: time, safety, adaptability, and fault tolerance. It is necessary to support additional properties, such as security, to support models dealing with several ones together, and to improve the provided assistance in the development and analysis of models.
- *Generation of Platform Specific Models (PSM) models*: An important part of the work performed in this activity is related with Platform Independent Models (PIM). A very

challenging work is to create model transformation tools that allow translating PIMs into PSMs. The ultimate goal will be to generate final code that can be executed in a particular run-time components framework, ensuring that the QoS-properties specified are met in the final system.

- *Extending run-time support*: the availability of run-time frameworks that support QoS-properties is limited. This support includes, for example, connecting two components from different vendors and ensuring that the global QoS properties are the required. The challenge is larger when dealing with multiple properties at the same time.
- *Technology transfer to industry*: The laboratory development of tools and techniques uses to validate them with small systems or experiments. The transfer of some of these achievements to the industry is important for disseminating the results of the research and to validate them with real life use cases. This will surely lead to the identification of required improvements and new lines of research.
- *Dissemination of the technology*: Two important activities to this respect are the participation in standards and to define techniques for packaging tools or platforms, in such a way that final deployment and installation is simplified.

4. Internal Reviewers for this Deliverable

Juan A. de la Puente (UPM)

Jose M. Drake (UC)