ARTIST 2
Network of Excellence

IST-004527 ARTIST2:
Embedded Systems Design

Activity Progress Report for Year 2

JPRA-NoE Integration

QoS Aware Components

Clusters:

Adaptive Real-Time

Real-Time Components

Activity Leader:

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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. We will bring together competencies in component-based design for hard and adaptive real-time systems, to produce advances that would be difficult to achieve without all three.

To achieve its aims, this activity requires competency in component models, middleware, networking infrastructures.

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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 it is feasible their interconnection and for deriving the non-functional characteristics of a group of connected components.
- Component frameworks to support the runtime composition of QoS aware components.

1.5 Problem Tackled in Year2

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. 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, it is needed support for the negotiation between components, for finding a suitable provider, and with the system, for getting the resources required for its execution. 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.

1.6 Comments From Previous Review

1.6.1 Reviewers' Comments

This task aims to define a list of QoS properties of components according to industrial sectors considered, develop an initial prototype of mechanisms for connecting components, and define mechanisms for the verification of properties.

The list of QoS properties are planned to appear in separate documents; mechanisms for component composition (component contracts) are under study; and some work has already been done on support for execution of QoS-aware components.

One of the reviewers has been a regular attendee at OMG meetings over the last 8 years and can testify to the strong involvement of ARTIST2 partners (CEA, Thales, INRIA, UPM, ..) on related topics discussed at the OMG. However, in the context of ARTIST2, a global picture of the various activities associated with completed or planned specifications targeted at the OMG and partner involvement would benefit the project and should help reinforce the synergies (see recommendations).

1.6.2 How These Have Been Addressed

A description of the standards where ARTIST-2 partners have been involved is described as part of an action at the project level.

2. Summary of Activity Progress

2.1 Previous Work

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 Current Results

2.2.1 Technical Achievements / Outcomes / Difficulties encountered

The work has been aligned in three main activities:

- Specification of QoS properties using UML profiles and aspect-based approaches
- Generation of analysable models from the UML models
- QoS support in run-time components frameworks

Specification of QoS properties

INRIA has designed a technique to express the semantics of quality of service in a way compatible with classical functional and behavioural properties. The language for specifying quality of service relies on well-accepted and well-defined structures of the UML notation. Quality of Service properties (extra-functional issues, e.g. time, throughput, memory usage) are specified separately from the functional ones (classical types and pre/postconditions), using statecharts. The transitions of these statecharts carry annotations that describe conditions of evolution as well as the side effects of this evolution on quality of service parameters. The composition of extra-functional statecharts with more classical, functional ones provides a specification that includes all aspects of the specification. QoS properties are thus handled

using the separation of concern approach. QoS statecharts are in turn attached to software components, thereby extending the component specification with extra-functional properties.

The composition of extra-functional properties is managed by mapping extra-functional properties to functional ones on the components that implement these extra-functional properties. For instance, memory consumption of given components A and B is mapped to a memory abstraction component, which defines how A's and B's needs are satisfied and how they interact (e.g. whether the total amount required is below a threshold). The Inria technique leverages the concept of relativity of functionality: properties may be extra-functional under some points of view and purely functional under other points of view.

UPM has continued its work on the specification of QoS properties using the UML profile on "QoS and Fault tolerance" [OMG05]. It has developed a set of guidelines to make it easier its use. UPM has also worked on the UML modelling of safety and time properties [Fer06] [Mig06a]. In particular, UPM has worked on the modelling of safety properties is based on the safety evaluation processes from THALES ATM and EUROCONTROL. Then, it was defined a conceptual model that allows the representation of the safety properties, rules and methods. The next step was to develop annotations for UML that allows the description of the mentioned safety concepts. This work is being done and two approaches are being explored: use of the QoS and FT profile and using a newly created safety profile. The main difficulties related with this work are the clear interpretation of the safety analysis process, the identification of the suitable elements in the conceptual model and the selection of the suitable UML mechanisms for the modelling.

During this year, CEA and INRIA have continued their effort towards the specification of temporal properties and their contribution to the MARTE UML profile. [OMG05a] is the last public deliverable, where a first definition of this profile is included.

Generation of analysable models from the UML models

UPM has also experimented the generation of safety analysis models out of the UML annotated models [Mig06]. In particular, there are two generators for fault-tree analysis (FTA) and FMECA. The generated models can be used as input for commercial analysis tools (Objecteering, RSA, UML2 and ITEM). Software architecture models are annotated with safety properties, and analysis models (FTA and FMECA) are generated based on these safe-aware software architectures. The software architectures and their safety annotations are based on guidelines of safety methodologies developed at Eurocontrol for air traffic control systems. These generators are useful for the evaluation and comparison of alternative architecture solutions in early phases of software development (http://www.dit.upm.es/str, http://www.modelware-ist.org).

As a result of the ARTIST2 Workshop: "Beyond AUTOSAR" an effort was made at CEA, in collaboration with the Univesidad de Cantabria to address the identified necessity to perform evaluation of QoS and timing requirements of the component based applications. For this it is necessary to obtain as much as possible information of the components implementation from the manufacturers but preserving the intellectual properties involved. The idea is to ask the hardware/software components manufacturers to somehow partially "grey" their black boxes, requiring them to bring a timing behavioural model of the components that will be delivered, as soon as possible in the integration process. These models should be an abstraction of the functional behaviour implemented in the binary code, which will made explicit all the control flow paths for the worst case situations, the internal interactions, the mutual exclusive shared resources (critical sections), and the execution time consumed by each independent segment of code. Specific configuration and deployment services are required to be able to characterize and complete the models on the concrete platform to use. Once defined and integrated, these models will serve to evaluate response times as well as performance characteristics from a

system wide viewpoint. The proposed strategy was presented in the 9th International Conference on Software Reuse 2006 [Med06].

QoS support in run-time components frameworks

UPM and UC3M have worked on the improvement of the QoS management in the Robocop framework [Alo06] (http://www.hitech-projects.com/euprojects/space4u/index.htm, http://www.dit.upm.es/str). The overall design has been modified in order to make it easier the handling of QoS properties. UPM has collaborated in the standardization process of the MPEG Multimedia Middleware (M3W). The QoS management APIs are part of the standard (http://www.chiariglione.org/mpeg/technologies/mpe-m3w/index.htm).

CEA and THALES are working on container extension mechanisms in order to add the QoS specification for container services by providing examples from our prototypes [Rob06] [Rob06a]. They have also participated on the development of the OMG QoS4CCM specification that can be downloaded from the OMG page (http://www.omg.org/cgi-bin/doc?ptc/2006-04-15) [OMG06].

2.2.2 Publications Resulting from these Achievements

[Alo06] Alejandro Alonso, Miguel García, Jaakko Kyro, Javier Fernández-Briones, Quality and Resouce Management in Components Framework, In the Workshop: Towards Off-the-Shelves Embedded Real-Time Systems, in the 9th International Conference on Software Reuse, Turin - Italy, 11 June 2006

[Fer06] J Fernández Briones, M De Miguel, J P Silva, A Alonso, *Integration of Safety Analysis and Software Development Methods*, 1st International Conference on System Safety Engineering IEE.

[Gar06] M. García Valls, I. Estévez Ayres, and P. Basanta Val, and Carlos Delgado-Kloos. *CoSeRT: A Software Framework for Composing Service-Based Real-Time Applications*. International Workshop on Enterprise and Networked Enterprises Interoperability (ENEI'2005). Lecture Notes in Computer Science. Nancy, France, September 5th, 2005

[Med06] J.L. Medina, P. López, J.M. Drake, S. Gerard and F. Terrier. *A Modeling Approach for the Verification of COTS Components-based Real-Time Systems*. In the Workshop: Towards Off-the-Shelves Embedded Real-Time Systems, in the 9th International Conference on Software Reuse, Turin - Italy, 11 June 2006

[Mig06] Miguel de Miguel, Javier Fernández Briones, Juan Pedro Silva, Alejandro Alonso, *Model Based Integration of Safety Analysis and Development*, ISORC 2006.

[Mig06a] Miguel A. de Miguel, Bernard Pauly, Thierry Person, Javier Fernández, *Model-Based Integration of Safety Analysis and Reliable Software Development*, WORDS 2005.

[OMG05] Object Management Group, UML Profile for Modeling Quality of Service and Fault Tolerance Characteristics and Mechanisms Final Task Force, OMG document number ptc/2005-05-02. http://www.omg.org/cgi-bin/doc?ptc/2005-05-02

[OMG05a] Object Management Group, A UML profile for MARTE. Initial Submission. http://www.omg.org/cgi-bin/doc?realtime/2005-11-01.pdf.

[OMG06] Object Management Group, Quality of Service for CORBA Components. Final adopted specification. http://www.omg.org/cgi-bin/doc?ptc/2006-04-15

[Rob06] S. Robert, A. Radermacher, V. Seignole, S. Gérard, V. Watine and F. Terrier, *Enhancing Interaction Support in the CORBA Component Model*.. In From Specification to Embedded Systems Application, pages 137-146, Manaus, Brazil. IFIP, August 2005.

[Rob06a] Sylvain Robert, Ansgar Radermacher, Vincent Seignole, Sébastien Gérard, Virginie Watine, François Terrier, *The CORBA Connector Model*. In Fifth International Workshop on Software Engineering and Middleware (SEM 2005), Lisbon, Portugal. ACM, September 2005.

[Sil06] Juan Pedro Silva, Miguel de Miguel, Javier Fernández Briones, Alejandro Alonso. *Safety Metrics for the Analysis of Software Architectures,* Workshop on Visual Modeling for Software Intensive Systems 2005

2.2.3 Workshops

Workshop : QoS-aware components
Paris (Saclay), 14 June 2006

The objectives of the workshop were to present, discuss and integrate the approaches from the interested partners in the area of QoS-aware components. In particular, some of the relevant topics included:

- QoS support in components frameworks
- Description of QoS characteristics based on UML
- QoS contract models
- Integration of different real-time QoS properties on the different phases of the development

3. Future Work and Evolution

3.1 Problem to be Tackled over the next 18 months (Sept 2006 – Feb 2008)

The work on this activity will continue the most important topics identified, that are the development 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 analysis models for the QoS properties modelled.
- Composition mechanisms for determining whether it is feasible components interconnection and for deriving the non-functional characteristics of a group of connected components and the resources needed to fulfil them.
- Component frameworks to support the runtime composition of QoS aware components and to interact with the QoS management subsystems.

Specification of QoS properties

One issue is how to include the description of extra-functional or QoS properties in functional models. There are results on this are such as two UML profiles with this aim: MARTE and "QoS and FT". There is some overlapping in the types of properties that can be described with them. In addition, there is little experience on their use. The goal is to experiment with them, using a suitable case study and QoS properties. The final results will be some guidelines for their use and an in-depth evaluation of both approaches. The use of other techniques, such a proposal based on aspects specification will be also explored. The integration of these frameworks is another topic of interest. CEA and INRIA have started an activity with the aim of integrating their research results in this area.

Generation of analysable models from the UML models

One of the advantages of the modelling of QoS properties is to check a system design meets the QoS requirements. For this purpose, the desirable approach is to be able to extract the information with respect to a QoS property and generate a model that can be used for analysis purposes. There are some problems related with this aim, such as to make sure that the QoS information provided is the appropriate and sufficient for the analysis and to evaluate the suitability of the different modelling approaches for this purpose.

On relation with the composition of components, the goal is to provide methods to assemble relevant quality properties and resource requirements. There are actions to develop contract models where the provided and required qualities between components are considered and ensured. These operations can be done at design time or at run time. In this case, it is needed to consider platform dependent transformations for including resource usage information to the quality levels that a component can provide.

QoS support in run-time components frameworks

It is clear that the problems are not only at the development phases. Another problem to handle is QoS component frameworks, that allows at runtime the identification, retrieving,

consistency checking, registering and composition of components. The QoS properties of the components need to be taken into account to ensure a proper system operation. For example, when trying to identify a suitable component for an application, it is necessary to make sure that in addition of the required functionality, it is able to provide a certain QoS with respect to some meaningful properties. There are some works in the group related with this topic. The goal will be to try to evaluate the relative merits of the runtime frameworks developed by the partners (UPM, THALES and CEA) and to propose an API that integrates the functionality required for this work and to try to promote it. CEA and THALES will use the connector extension of CCM to add fault tolerance properties.

3.2 Current and Future 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. **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.**
4. 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.

3.3 Indicators for Integration

This activity will strengthen 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.

3.4 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

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.

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- AOSD network of excellence (2005-2009)
- French national RNTL Faros research project 2006-2009
- French national RNTL OpenEmb research project 2006-2009
- SPEEDS ITEA project 2006-2009

3.5 Internal reviewers

Juan A. de la Puente

Pablo Basanta

4. Annex 1: Answers to reviewer's comments

This annex includes the response to the reviewer's comments on October 2006.

This task this year consisted of identifying notations for the description of functional and non functional QoS properties using UML profiles, generating analysable models and defining a contract model to express component interaction with regard to QoS.

The document is not always clear about what has been done, what is the current work and what is the future. It would be beneficial to organize in each section, the description according to the three domains of activities.

> *The document has been carefully reviewed to try to clarify its content and the status of the work. Each section has been organized according to the main three lines of work.*

Section 1.5 in problem tackled in year2 sometime the future tense is used bringing some confusion on what has been achieved. The last paragraph is more a "state of the art" paragraph, but Artist2 is not clearly positioned toward these issues: what are the plan to address this? What will Robocop and CCM bring?"

> *The use of verb tenses has been reviewed and corrected. With respect to Robocop and extensions of CCM: the goal is to have runtime support for components, supporting QoS characteristics. Robocop and extensions of CCM are two approaches subject of work from two partners of the activity. The goal is to compare both approaches and establish requirements, functionality and API definition in a way that integrates both works.*

Section 2.1 previous work: the future tense is used bringing some confusion.

> *The use of verb tenses has been reviewed and corrected*

Section 2.2 current results: this section will benefit from a clear organization according to the three areas and perhaps additional concrete reference to detailed work (URL, Reference of specifications or articles).

> *The content of this section has been improved. The secetion has been structured according to the three domains of work in this activity. A number of additional references have been included and cross-references to them has been included in the text.*

Section 2.2.3: the present tense is used for a past workshop?

> *Fixed.*

After 2 years, the QoS properties considered are not described.

> *Some QoS properties are described in the UML profile for QoS and FT. In addition QoS properties for safety has also been described. Some references have been included in the document.*