



IST-214373 ArtistDesign  
Network of Excellence  
on Design for Embedded Systems

Cluster Progress Report for Year 4

Cluster:  
**Operating Systems and Networks**

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*Policy Objective (abstract)*

The objective of this cluster is to build the fundamental basis of a new real-time software technology that can provide a more efficient and predictable support to the development of future embedded systems, characterized by high complexity dynamic behaviour and distributed organisation. To cover these issues, the cluster is organized into 3 activities:

1. JPRA Cluster: Resource-Aware Operating Systems
2. JPRA Cluster: Scheduling and Resource Management
3. JPRA Cluster: Real-Time Networks

## Versions

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# 1. Overview

## 1.1 High-Level Objectives

The high level objective of this cluster is to build the fundamental basis of a new real-time software technology that can provide a more efficient and predictable support to the development of future embedded systems, characterized by high complexity dynamic behaviour and distributed organisation. In particular, the new software technology should:

- support scalability to facilitate the porting of control applications to different platforms;
- simplify the management of resources to control the growing complexity and distribution of embedded systems;
- take advantage of parallel processing platforms, such as multicores, in order to satisfy timing and adaptivity requirements;
- be light-weight to optimize the usage of scarce resources in tiny embedded computing devices;
- increase programming flexibility, for specifying functional and performance requirements to simplify test and verification;
- enable run-time reconfigurability and functionality updates to deal with the dynamics and ubiquitous nature of the supporting computing infrastructure;
- increase programming productivity, by raising the level of abstraction of the resource management services;
- increase system adaptivity to react to environmental changes, still providing a sufficient level of performance;
- be robust to tolerate transient and permanent overload conditions due to wrong design assumptions or unpredictable changes.

A means to achieve such a goal is to develop a research platform for real-time systems to share competencies, resources, and tools targeting at the development of applications, such as control systems, with performance and timing requirements. The use of a shared platform is essential for experimenting new real-time software technology, including novel scheduling algorithms, resource management techniques, communication paradigms, energy-aware policies and overload handling approaches to increase robustness and predictability. A shared platform also facilitates the transfer of research results to industry, as it allows teaching practical knowledge of concepts and techniques. In addition, several solutions can be developed and tested in parallel in different partner sites, allowing the evaluation of the most appropriate approach for specific applications.

Specific research topics addressed in this cluster are related to operating systems and networks, with particular emphasis on scheduling and resource management, including energy-aware strategies and exploitation of parallelism in multicores.

**-- Changes wrt Y3 deliverable --**

No changes with respect to Year 3.

## 1.2 *Industrial Sectors*

The industrial sectors that can benefit from adaptive real-time technology include Consumer Electronics, Industrial Automation, and Telecommunications.

Consumer Electronics (CE) products range from miniature cameras and MP3 players to advanced media servers and large displays. These systems are prone to intermittent overload conditions that could degrade the performance in an unpredictable fashion [Wus05, Loo03]. To address these problems, the cluster aimed at integrating the most recent research results achieved in the real-time community to build flexible as well as predictable real-time systems that can react to load changes and perform QoS adaptation in a controlled fashion.

In the area of Industrial Automation there is a trend to use distributed solutions for connecting the general plant actuators, sensors and the controllers. At the same time, there is an increase of demands for new options and improvements in the automation results, fetching more control of plant secondary data. The contribution of the cluster in this domain was to investigate how to achieve predictability and adaptivity in distributed systems.

Embedded systems for telecommunications applications are mainly targeted to the interfaces between communication technologies and to coding/decoding operations. They may be considered real-time as they have timeliness requirements for some of the critical operations they must perform. The work on resource reservation carried out in the cluster was of crucial importance to manage the increased complexity of the applications in this domain.

### -- Changes wrt Y3 deliverable --

No changes with respect to Year 3.

## 1.3 *Main Research Trends*

Embedded systems are evolving towards applications that have more and more functionalities and adaptive behaviour to cope with a large set of environmental conditions and different user requirements. On one hand, the increasing complexity of the applications requires the use of multicore platforms capable of exploiting hardware parallelism to meet high-performance requirements and timing constraints. On the other hand, the rapid evolution of the hardware platforms requires new abstraction models to speed up application design and portability.

To efficiently operate in dynamic environments, a system must be adaptive; that is, it must be able to adjust its internal strategies in response to a change in the environment, to keep the system performance at a desired level. Implementing adaptive embedded systems requires new resource abstractions and specific support at different architecture levels.

Hardware platforms are evolving towards multicore architectures, which exploit parallelisms to improve performance while containing power consumption. New solutions combine heterogeneous processing elements (CPUs, GPUs, FPGA modules, etc.) to achieve higher performance. However, programming such a platforms is not trivial and a lot of effort is being devoted by the research community to build adequate abstractions that can simplify programming while exploiting the available parallelism as much as possible.

### -- Changes wrt Y3 deliverable --

More emphasis on multicore platforms to increase performance and higher abstraction layers to speed up application design and portability.

## 2. State of the Integration in Europe

The research trends outlined in Section 1.3 are being addressed at different levels by several research groups and industrial companies.

### 2.1 *Brief State of the Art*

Given the evolution of computer architectures, an increasing attention is being devoted toward multicore platforms and large networked systems, including cloud computing. This section briefly summarizes the most recent results achieved in the last two years.

The National Technical University of Athens and the Scuola Superiore Sant'Anna of Pisa investigated techniques [25-27] for real-time interaction between people and applications over a service oriented Infrastructure, where processing, storage and networking needs to be combined and delivered with guaranteed levels of service.

The real-time group at University of North Carolina is investigating new schedulability results for testing the schedulability of real time applications under different architecture scenarios and task models [1-8]. Several results in this groups have also been obtained with the collaboration of European researchers. The group at Polytechnic Institute of Porto started addressing multiprocessor scheduling with resource sharing [9, 10]. People at the Swiss Federal Institute of Technology of Zurich (ETH) are investigating the analysis of energy-aware scheduling on multiprocessor platforms [11-15]. At EPFL of Lausanne new algorithms are being developed for implementing efficient video coding standards on multicore platforms [16]. The group at University of York is working to extend the execution support of ADA processes on multiprocessor platforms [17-19]. The Retis Lab at the Scuola Superiore Sant'Anna of Pisa is working on implementing a virtual multi-processor abstraction layer to apply resource reservation in the Linux kernel [20-24].

Design of real-time component-based applications on open platforms: Combining component-based development and resource reservation techniques, a methodology has been developed that allows designing hard real-time component-based applications that are going to be installed in open platforms, in which the rest of the workload supported by the platform is unknown [28].

Modelling real-time applications based on resource reservations: The MAST 2 metamodel has been recently proposed for modelling real-time systems. Two new classes named `Virtual_Schedulable_Resource` and `Virtual_Communication_Channel` have been introduced for modelling the schedulable entities in real-time applications that are designed and executed relying on a resource reservation paradigm [29].

Schedulability Analysis and Optimization in Heterogeneous Distributed Real-Time Systems: Composition mechanisms have been developed to enable us to combine different FP and EDF response-time analysis techniques for checking the schedulability of heterogeneous systems. Additionally, priority and scheduling deadline assignment techniques were combined into a new algorithm called HOSPAs (Heuristic Optimized Scheduling Parameters Assignment), for optimizing the assignment of priorities and scheduling deadlines to tasks and messages in heterogeneous distributed hard real-time systems. [30].

Modeling switches and routers in MAST (Modeling and Analysis Suite for Real-Time Applications): We have introduced the schedulability model that will enable an automatic schedulability analysis of an application using switched networks, in particular, AFDX networks are supported [31]. Schedulability analysis technique for AFDX networks have also been developed [32].

Distribution middleware: An adaptation of a distribution middleware based on the end-to-end flow model to High-Integrity (HI) systems. An API has been proposed to develop High-integrity Distributed Real-Time (HDRT) systems in Ada by integrating the real-time end-to-end flow model with the Ravenscar profile (widely used in for single-processor systems but not for distributed ones) [33]. In the same area of distribution middleware, Cantabria and Madrid-UPM have worked in the integration of distribution middleware into an MDE development process for HI systems [UC-UPM-1]. Finally, an Analysis of the real-time capabilities of DDS (Data Distribution Service for Real-Time Systems) has been made [34].

Several ArtistDesign Partners are also involved in different European projects to develop methodologies and infrastructures for simplifying the use and the analysis of multicore platforms for specific applications domains of industrial interest.

For example, in the FRESCOR project (FP6/2005/IST/5-034026) [35], the main objective was to develop advanced real-time techniques to target reconfigurable distributed architectures. This has been achieved by creating a contract model that specifies the application requirements, the resources that must be guaranteed and how the system can distribute spare resources to achieve the highest efficiency. The contracts is integrated with a component-based framework and provides the required level of abstraction to make the component model independent of the underlying implementation and hardware architecture.

The ACTORS project (Adaptivity and Control of Resources in Embedded Systems) [36] addressed design of resource-constrained software-intensive embedded systems with high requirements on adaptivity and efficiency. Virtualization techniques, feedback control, and data-flow programming models have been used to achieve spatial and temporal separation of concerns, adaptive behaviour, and resource optimization. Combining feedback control with resource reservations allows handling incorrect reservations, reclaim and redistribute unused resources, and adjust to dynamic changes in resource requirements. Data-flow models, such as actor models, provide the proper foundation for implementation of efficient, component based, and adaptive algorithms.

The PREDATOR (Design for predictability and efficiency) project [37] is concerned with embedded systems that are characterized by efficiency requirements on the one hand and critical constraints on the other. This combination of requirements typically occurs in application domains such as automotive, aeronautics, multi-media and industrial automation. The main objectives are to improve the design and development methods for safety-critical embedded systems, to develop tools that support these development methods, and to provide architectural platforms that exhibit the desired predictability properties.

The IRMOS (Interactive Realtime Multimedia Applications on Service Oriented Infrastructures) project [38] aims at enabling real-time interactions between people and applications over a Service Oriented Infrastructure, where processing, storage and networking needs to be combined and delivered with guaranteed levels of service.

The S(o)OS (Service-oriented Operating Systems) project [39] addresses the needs of future distributed systems by drawing from service-oriented architectures (SOA) and the strengths of Grids.

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**-- Changes wrt Y3 deliverable --**

This section has been updated with new contains and references to new research results and projects.

## **2.2 Main Aims for Integration and Building Excellence through ArtistDesign**

Combining the results achieved by the various research groups is only possible by a tight interaction among the cluster participants. Hence, the aim of the integration through ArtistDesign is to facilitate communication among cluster members in order to:

- Improve the understanding of the key features to be added at different architecture levels (operating system, network, middleware, and language) to support adaptive real-time systems;
- Clarify the terminology to provide a common language for exchanging information between different cluster and research communities;
- Build a common operating system platform to perform experiments and develop tools that can be shared by the different research teams;
- Identify new research directions aimed at overcoming the problems encountered during the integration phase;
- Interact with industries to understand their problems and identify possible solutions;
- Form new consortia and make concrete project proposals to address specific research problems or develop critical applications of industrial interest.

**-- Changes wrt Y3 deliverable --**

No changes with respect to Year 3.

### **2.3 Other Research Teams**

The cluster had several interactions with the following research teams:

- High Performance Computing Centre of the University of Stuttgart – HLRS (reference persons: Stefan Wesner, Lutz Schubert) on development and support of distributed programming models and tools for parallel programming on supercomputing systems.
- National Technical University of Athens, Greece (reference persons: Gregory Katsaros, Spyridon Gogouvis, Kleopatra Konstanteli, Dimosthenis Kyriazis) on real-time scheduling and resource management in cloud computing.
- United Technologies Research Center, Cork, Ireland, on real-time operating systems and energy management in wireless sensor networks.
- University of Illinois at Urbana Champaign (reference persons: Prof. Lui Sha, Prof. Tarek Abdelzaher, and Prof. Marco Caccamo) on wireless communication protocols for real-time distributed embedded systems.
- University of Virginia (reference persons: Prof. John Stankovic and Prof. Sang Son) on adaptive real-time systems for sensor networks.
- University of Lund (reference persons: Karl-Erik Arzen and Anton Cervin) on feedback control techniques for adaptive real-time systems.
- University of California at Berkeley (reference person: Alberto Sangiovanni Vincentelli) on the design of component-based operating systems.
- Philips Research Eindhoven (reference persons: Dr. Sijr van Loo) on resource management for consumer electronics.
- NXP (reference persons: Dr. Liesbeth Steffens) on resource management for consumer electronics.
- Ericsson Mobile Platforms (reference person: Dr. Johan Eker) on resource reservation and adaptive QoS management.
- Microchip Technology (reference person: Dr. Antonio Bersani) on real-time embedded platforms for monitoring and control.
- Carnegie-Mellon University (reference person: Prof. Raj Rajkumar) on wireless sensor networks, cooperative computing, and QoS adaptation.
- Seoul National University (reference persons: Dr. Jungkeun Park, Dr. Kanghee Kim), on distributed embedded systems and stochastic analysis of periodic task sets.
- Malardalen University, Sweden (reference person: Dr. Thomas Nolte), on integration of networked subsystems in resource constrained environments and on stochastic analysis of hybrid task sets.
- Saarland University, Germany (reference person: Prof. Reinhard Wilhelm), to investigate the use on limited preemptive scheduling to increase systems predictability.
- University of Dortmund, Germany (reference person: Prof. Peter Marwedel) on the use of real-time kernels for embedded applications.

- University of Bologna, Italy (reference person: Prof. Luca Benini), on a simulation environment for real-time multi-core systems.
- EPFL of Lausanne, Switzerland (reference person: Prof. Marco Mattavelli), on cache-aware scheduling algorithms that optimize memory usage in data-flow applications.
- Airbus, France (reference person: Dr. Benoit Triquet), on real-time operating systems for safety critical avionic applications.
- Bosch, Germany (reference person: Dr. Simon Kramer), on real-time operating mechanisms for increasing predictability and efficiency in automotive applications.
- Absint, Germany (reference person: Dr. Christoph Cullmann), on the use of timing analysis tools for optimally placing preemption points in the task code to reduce stack size and worst-case execution times.

**-- Changes wrt Y3 deliverable --**

New collaborations have started with the High Performance Computing Centre of the University of Stuttgart (Germany), the National Technical University of Athens (Greece), and the United Technologies Research Center in Cork (Ireland).

## **2.4 Interaction of the Cluster with Other Communities**

### **Interaction with the community on Supercomputing systems**

The Scuola Superiore Sant'Anna Pisa (Tommaso Cucinotta) collaborated with the High Performance Computing Centre of the University of Stuttgart – HLRS (reference persons: Stefan Wesner, Lutz Schubert) on the development and support of distributed programming models and tools for parallel programming on supercomputing systems.

### **Interaction with the community on Wireless Sensor Networks**

The Scuola Superiore Sant'Anna Pisa (Paolo Pagano, Antonio Romano) collaborated with the United Technologies Research Center, Cork, Ireland, on real-time operating systems and energy management in wireless sensor networks. The Scuola Superiore Sant'Anna of Pisa (Paolo Pagano, Daniele Alessandrelli) also collaborated with University of Virginia (Prof. Stankovic) on reliable wireless sensor networks for assisted living.

CISTER-ISEP (Porto) collaborated with TinyOS working groups in the implementation of ZigBee /IEEE802.15.4 on that operating system, namely the TinyOS 15.4 and TinyOS ZigBee Working Groups. Moreover, several tools for the design, analysis, deployment and operation of WSNs were made available to the WSN community, such as the Open-ZB protocol stack, cluster-tree OPNET simulation models and the Z monitor.

### **Interaction with the community on Cloud Computing**

The Scuola Superiore Sant'Anna Pisa (Tommaso Cucinotta, Giuseppe Lipari, Juri Lelli) collaborated with the National Technical University of Athens (Greece) (reference persons: Gregory Katsaros, Spyridon Gogouvtis, Kleopatra Konstanteli, Dimosthenis Kyriazis) on service oriented infrastructure, where processing, storage and networking needs to be combined to deliver guaranteed levels of service in cloud computing systems.

### **Interaction with the info-mobility community**

The Scuola Superiore Sant'Anna Pisa (Paolo Pagano, Matteo Petracca, and 3 PhD students) had started a fruitful collaboration with the community working on intelligent transportation systems (i-Transportation), interacting with a set of local enterprises (Intecs SpA, Aleph srl, Parkeon SpA, Montalbano Technology SpA) to develop wireless sensor networks for monitoring urban traffic and parking slots. Additional collaborations have been carried out with the University of Virginia in the domain of Wireless Sensor Networks, Kingston and Queen Mary Universities in London for computer vision techniques tailored to resource constrained devices.

### **Interaction with the open-source software community**

The Scuola Superiore Sant'Anna joined the Open Source Automation Development Lab (OSADL), whose goal is to promote and support the usage of Open Source software in the automation industry and for embedded systems. For the time being, these activities mainly focus on the Linux kernel but are, by no means, restricted to it. In addition to the development of Open Source software components, OSADL has expanded the principle on Open Innovation to the conveyance of legal advice, to technical support, to marketing activities and to conferences, seminars and training courses for its members.

### **Interaction with the community of pervasive computing**

UC3M has been in contact with the Pervasive Laboratory of University of Twente (Prof. Hans Scholten) to exchange work and knowledge in the iLAND project and how to integrate real-time in ubiquitous computation environments through specialized middleware.

### **Interaction with the robotics community**

UnivPorto and Aveiro collaborated with the RoboCup Federation, in the Middle Size League, in the definition of a real-time wireless communication protocol over IEEE 802.11, together with a lightweight middleware, to support the coordinated play of the robotic soccer teams.

### **Interaction with the control community**

The Scuola Superiore Sant'Anna of Pisa, the University of Lund, and the University of Catalonia are continuing to collaborate to integrate control theory and real-time scheduling. From one hand, feedback control schemes are investigated to make real-time embedded systems more adaptive to variable load conditions. On the other hand, real-time and control theory is being integrated to explore new event-driven approaches to optimize resource usage while meeting control performance constraints.

### **Interaction with the industrial communications community**

Catania maintained a close collaboration with the industrial communications community, mainly through the participation in joint research projects aiming at promoting the use of wireless communication, resulting in a diversity of new protocols and analysis tailored to industrial environments, with the required levels of timeliness, robustness and flexibility.

### **Interaction with the model-driven engineering community**

Cantabria, Madrid-UPM and Madrid-UC3M have been involved in a number of collaborative actions with the model-driven engineering community, mainly in terms of refining the models used in recent standards, such as MARTE, and combining with QoS-oriented middleware such as DDS, so that schedulability analysis techniques can be used.

### **Interaction with the cluster on compilers and timing analysis**

The collaboration with the cluster on compilers and timing analysis is continuing on techniques for reducing the variability of task execution times. Non-preemptive scheduling approaches are being investigated together with cache-aware scheduling to reduce worst-case execution times of tasks.

#### **-- Changes wrt Y3 deliverable --**

This section is completely new. Additional collaborations were established with the communities of cloud computing, supercomputing systems, and info-mobility systems.

### 3. Overall Assessment and Vision for the Cluster

#### 3.1 Final Overall Assessment

The work produced by the cluster since the start of the NoE was excellent. The major benefit of the ArtistDesign NoE was to act as a large research forum, where groups with different expertise had the possibility to interact and collaborate for addressing challenging research problems in the complex domain of embedded systems. Such a collaborative work produced the following significant results:

- Challenging research issues. Different collaborations took place within the cluster that allowed exploiting complementary expertise available among the partners to address complex problems and propose interesting solutions. This can be assessed by the large number of joint papers produced by the cluster members. Some of the most relevant results achieved so far include:
  - o The implementation of a real-time scheduler in the Linux kernel, with a support for resource reservation.
  - o A programming framework to support resource reservation of concurrent real-time applications on multi-core platforms, considered by Ericsson for software development in next generation cell phones.
  - o The integration of cache-aware analysis and limited-preemptive scheduling (together with the Cluster on Compilers and Timing Analysis) to increase predictability as well as efficiency of safety critical applications. The work has been carried out in collaboration with Airbus (for avionic applications) and Bosch (for automotive systems).
  - o The toolset to design, analyse, configure and deploy dense WSNs, in part built within the ARTEMIS EMMON project, including the Open-ZB ZigBee protocol stack and the Z monitor.
  - o A middleware and communication protocol for teams of mobile robots that are self-reconfigurable and provide efficient support to intensive interactions and which have been adopted by several teams in the RoboCup Middle Size League.
  - o The MAST suite (Modelling and Analysis Suite for Real-Time Applications), which was enhanced with more networking components and analysis, namely for switched networks such as AFDX;
  - o A number of communication protocols and tools, developed for improving predictability and adaptivity in (industrial) networked embedded systems.
  - o The development of a comprehensive taxonomy for the resources currently used in embedded real-time systems.
- European projects. Several European projects started thanks to the integration activities triggered by ArtistDesign. Examples are FRESCOR; ACTORS, PREDATOR, IRMOS, MORE, INTERESTED, FlexWARE, MADES, S(o)OS, iLAND, RT-MODEL, and HI-PARTES.
- Bridge between Industry and Academia. Several contacts with the industry have been established within ArtistDesign, which contributed to reduce the huge gap existing between the theoretical work carried out in the university and the applications developed by the companies. Example of industries that collaborated with the cluster

include Airbus, Bosch, Magneti Marelli, General Motors, Ericsson, Philips, Microchip Technology, Alcatel Lucent, Telecom. A significant effort has been made by the cluster to precisely define a common language between industry and academia.

- Dissemination. The cluster members were deeply involved in the organization of first class conferences and workshops all over the world to disseminate the achieved results. Example of conferences include RTSS, RTAS, ECRTS, CPS Week, RTCSA, ETFA, RTNS, HSCC, Ada Europe, DATE, EmSOFT. From the educational side, a large number of graduate courses, summer schools, workshops, and training laboratory activities have been organized to disseminate the knowledge of the cluster to graduate and PhD students.

-- The above is new text, not present in the Y3 deliverable --

### 3.2 *Assessment for Year 4*

The collaboration among the cluster participants has been fruitful and is demonstrated by the relevant number of joint publications, projects and events organized within the cluster. A summary of the achievements in Year 4 is reported in the next session, whereas details and more information can be found in the three activity reports.

-- The above is new text, not present in the Y3 deliverable --

### 3.3 *Indicators for Integration*

During year 4, interactions between partners can be measured as follows:

- 70 joint publications in international journals and proceedings related to real-time and embedded computing systems (see the Activity Deliverables). The plan was 10 Joint publications/year.
- 14 Keynote speeches by team leaders of the cluster (see the Activity Deliverables).
- Creation of a repository for relevant publications, algorithms, and libraries related to real-time operating systems. URL: <http://tcrts.org/>
- Impact on industrial practice in the area of real-time scheduling:
  - Use of resource reservation by Ericsson
  - Use of predictable real-time methodologies by Airbus and Bosch
  - Use of multi-core kernel for automotive applications by Magneti Marelli
- 4 technical meetings (see Section 4.1)
- 7 exchanges, including PhD student and faculty exchanges (see Section 4.2).
- Integration of tools existing at the partner sites (see Section 4.3)
  1. A simulation environment for Multimedia Sensor Networks (SSSA, Pisa)
  2. PartiCore – A Partitioning Tool for Multi-core Reservations (SSSA, Pisa)
  3. YaoSim: Yet Another Operating system SIMulator (SSSA, Pisa)
  4. Marte OS (University of Cantabria)
  5. HaRTES Ethernet switch (University of Aveiro)
  6. Flexible Time-Triggered framework (University of Porto)
  7. iLAND (UC3M)

- Joint organization of 26 workshops, tutorials, special sessions in international highly recognized conferences (see Section 4.4.1). The target was 3 workshops/year for discussing new trends and solutions on operating systems and networks.
  1. Conference: CPSWEEK 2011, Chicago, Illinois, USA, April 12-14, 2011.
  2. Conference: IEEE RTAS 2011, Chicago, Illinois, USA, April 12-14, 2011.
  3. Conference: ICCPS 2011, Chicago, Illinois, USA, April 12-14, 2011.
  4. Conference: HSCC 2011, Chicago, Illinois, USA, April 12-14, 2011.
  5. Conference: IEEE RTSS 2011, Vienna (Austria), Nov. 30 - Dec. 2, 2011.
  6. Conference: ECRTS 2011, Porto, Portugal, July 6-8, 2011.
  7. Conference: IEEE ETFA 2011, Toulouse, France, September 5-9, 2011.
  8. Conference: IEEE RTCSA 2011, Toyama, Japan, August 28-31, 2011.
  9. Conference: RTNS 2011, Nantes, France, September 29-30, 2011.
  10. Conference: DATE 2011, Grenoble, France, March 14 – 18, 2011.
  11. Conference: MED 2011, Corfu, Greece, June 20-23 2011.
  12. Special Track in INDIN 2011, Caparica, Portugal–27-29 July, 2011
  13. Workshop: OSPERT 2011, Porto, Portugal, July 5th, 2011.
  14. Workshop: WCET 2011, Porto, Portugal, July 5th, 2011.
  15. Workshop: RTN 2011, Porto, Portugal, July 5th, 2011.
  16. Workshop: WATERS 2011, Porto, Portugal, July 5th, 2011.
  17. Workshop: RTSOPS 2011, Porto, Portugal, July 5th, 2011.
  18. Workshop: NeRES 2011, Porto, Portugal, 10-11 November, 2011.
  19. Workshop: APRES 2011, Chicago, Illinois, USA, April 11, 2011
  20. Workshop: CRTS 2011, Vienna, Austria, November 29th, 2011.
  21. Workshop: AVICPS 2011, Vienna, Austria, November 29th, 2011.
  22. Workshop: WCTT 2011, Vienna, Austria, November 29th, 2011.
  23. Workshop: SOMRES 2011, Vienna, Austria, November 29th, 2011.
  24. Workshop: RTSS@Work 2011, Vienna, Austria, November 29th, 2011.
  25. Workshop: Workshop on Real-Time System Models for Schedulability Analysis, University of Cantabria, Santander, Spain - February 7-8, 2011.
  26. Workshop: Ada Workshop (IRTAW-15), Liébana (Cantabria), Spain, September 2011
- Organization of joint educational activities on real-time operating systems and networks, like training courses, summer schools, or student competitions (see Section 4.4.2):
  - Graduate Course on Combinatorial Optimization, SSSA, Pisa – Oct.-Nov. 2011.
  - Graduate Course on Android Framework, SSSA, Pisa, Nov. – Dec. 2011
  - ArtistDesign Summer School in China 2011, 11-12 August 2011.
  - Graduate Course at Universidad del Pays Vasco, Bilbao, Spain, 3-4 May 2011.
  - Graduate Course at ENSIAS, Rabat, Morocco, 19-21 December 2011.
  - Graduate Course on Real-Time Kernels for Microcontrollers, Pisa, June 13-17, 2011
- Involvement on standardization activities (see Section 4.4.3):
  - UML Profile QoS and Fault Tolerance (UP Madrid)
  - Ada (University of York)
  - POSIX 1003 (University of Cantabria)
  - MPEG Multimedia Middleware (M3W) (UP Madrid)
  - Wireless Industrial communication networks SC65C, Working Group 16 (University of Catania)
  - TinyOS IEEE802-15-4/Zigbee support (Polytechnic Institute of Porto)
  - Linux kernel (SSSA, Pisa)

**-- Changes wrt Y3 deliverable --**

This section has been updated with the achievements in Year 4.

### **3.4 Future Directions**

The future direction of the cluster is to build a significant amount of knowledge on problems, methodologies, techniques, and tools for embedded systems with highly dynamic behaviour, so that it can be disseminated in the industry and in the academia to educate next generation engineers to make embedded systems more robust, more efficient, more flexible, and more predictable than what is possible today.

There are strong indications that adaptive real-time techniques will continue to be important for the embedded systems community. Scheduling and resource management must allow a higher flexibility to handle future applications, which are going to be more dynamic in terms of resource requirements.

The current industrial trend of developing multi-core platforms is introducing a higher degree of complexity that is pushing the research community towards new approaches and methodologies. In fact, the traditional programming model used so far in uniprocessor platforms is quite inadequate for systems consisting of multiple cores and needs to be completely revisited.

To reduce design times and simplify portability of applications on top of different architectures, the trend is to abstract the physical platform resources with a set of virtual resources, which can be managed independently of the physical resources.

Energy-aware and temperature-aware strategies are also becoming very relevant at different architecture levels to prolong battery lifetime and reduce chip damages due to high temperatures, respectively.

**-- The above is new text, not present in the Y3 deliverable --**

## 4. Cluster Participants

### -- Changes in the Cluster Participants w.r.t. Y3 deliverable --

Prof. Sverre Hendseth (Norwegian University of Science and Technology) and Prof. John Stankovic (University of Virginia) were added in the list of affiliated partners. The Team leader of the University of Pavia (affiliated to Pisa) was updated.

### 4.1 Core Partners

<b>Cluster Leader</b> <b>Activity Leader for “Resource-Aware Operating Systems”</b>	
	Prof. Giorgio Buttazzo Scuola Superiore Sant’Anna (SSSA), Pisa (Italy) URL: <a href="http://feanor.sssup.it/~giorgio/">http://feanor.sssup.it/~giorgio/</a>
Technical role(s) within ArtistDesign	Coordinating the cluster on Operating Systems and Network and the activity entitled “Resource-Aware Operating Systems”. Providing support on real-time scheduling, operating systems, resource management, overload handling, energy aware algorithms, and quality-of-service strategies.
Research interests	Real-time operating systems, dynamic scheduling algorithms, quality of service control, multimedia systems, advanced robotics applications, and neural networks.
Role in leading conferences/journals/etc in the area	Editor-in-Chief of the Journal of Real-Time Systems (Springer). Associate Editor of the Journal of Embedded Computing (Cambridge International Science Publishing). Executive Board Member of the Euromicro Conference on Real-Time Systems. Program Chair of RTSS’01, ECRTS’03, EMSOFT’04, HSCC’07. General Chair of RTSS’02, EMSOFT’04, ECRTS’07. Reviewer for Real-Time Systems, IEEE Transactions on Computers, ACM Transactions on Embedded Computing. Program committee member of most real-time related conferences.
Notable past projects	“FIRST: Flexible Integrated Real-time Systems Technology”, IST-2001-32467 (2002-2005) investigated advanced scheduling for handling applications with various real-time requirements.

	<p>“OCERA: Open Components for Embedded Real-time Applications”, IST-2001-35102 (2002-2005) integrated advanced real-time mechanisms in open-source kernels.</p> <p>“FABRIC: Federated Applications Based on Real-time Interacting Components”, IST-2001-37167 (2002-2003) investigated QoS management methods for home networks.</p> <p>“ARTIST: Advanced Real-Time Systems”, IST-2001-34820 (2002-2005) investigated adaptive real-time systems for QoS management.</p> <p>“TRACS - Flexible Real-Time Architecture for Traffic Control Systems”, ESPRIT III project No. 6373 (1992-1995) investigated real-time techniques for vessel control systems.</p>
Awards	<p>Best paper Award at the 10<sup>th</sup> Int. Conference on Real-Time and Embedded Computing Systems and Applications (RTCSA 2004), Gothenburg, Sweden, August 2004. Paper: “The Jitter Margin and Its Application in the Design of Real-Time Control Systems”.</p> <p>Award for the best paper and presentation at the ANIPLA Workshop on Operating Systems for Industrial Control Applications, Milan, November 18, 1999.</p> <p>HUSPI Award given by Honeywell for the best journal publication on robotic systems, November 1987.</p>
Further Information	Senior Member of IEEE

<b>Team Leader</b> <b>Activity Leader for “Scheduling and Resource Management”</b>	
	<p>Professor Alan Burns            University of York, UK            URL: <a href="http://www.cs.york.ac.uk/~burns">www.cs.york.ac.uk/~burns</a></p>
Technical role(s) within ArtistDesign	Undertakes research in real-time systems scheduling, particularly for flexible systems. Also concerned with the development of programming languages for this domain.
Research interests	Scheduling, languages, modelling and formal logics.
Role in leading conferences/journals/etc in the area	Previous Chair of the IEEE Technical Committee on Real-Time Systems. Edited special issue of ACM Transactions on Embedded Systems (on education).
Notable past projects	DIRC – Dependability Interdisciplinary Research Collaborations – A large, UK, 6-year, multisite project looking at dependability of computer-based systems. Burns was a PI and managed the

	<p>work on temporal aspects of dependability.</p> <p>FIRST – EU funded project concerninf flexible scheduling</p> <p>FRESCOR – EU follow on project to FIRST</p>
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<b>Team Leader</b>	
	<p>Prof. Gerhard Fohler</p> <p>Technical Univeristy of Kaiserslautern (TUKL)</p> <p>URL: <a href="http://www.eit.uni-kl.de/fohler">www.eit.uni-kl.de/fohler</a></p>
<p>Technical role(s) within ArtistDesign</p>	<p>The role of TUKL is to investigate resource management policies for controlling the quality of service in multimedia applications. The team is leading the activity on Adaptive Resource Management for Consumer Electronics and is involved in the development and analisys of algorithms for video streaming applications. A further focus is on flexible scheduling, with the aim of integrating offline and online approaches.</p>
<p>Research interests</p>	<p>Real-time scheduling, integration of offline and online scheduling, QoS management, video streaming and media processing.</p>
<p>Role in leading conferences/journals/etc in the area</p>	<p>Chairman, technical committee on real-time systems, Euromicro</p> <p>Member of executive board technical committees on, IEEE real-time systems, IE embedded systems</p> <p>Area editor real-time, Journal of System Architecture, Elsevier</p> <p>Program chair, IEEE Real-Time Systems Symposium, 2006</p> <p>Program chair, subtrack real-time systems, DATE 2005-2007</p> <p>Program committee member of most real-time related conferences</p>
<p>Notable past projects</p>	<p>FRESCOR - Framework for Real-time Embedded Systems based on COntrActs, EU IST STREP</p> <p>WASP - Wirelessly Accessible Sensor Populations, EU IST IP</p> <p>BETSY - BEing on Time Saves energy continuous multimedia experence with low battery power, EU IST STREP</p> <p>FIRST - Flexible Integrated Real-Time System Technology, EU IST STREP</p> <p>FABRIC: “Federated Applications Based on Real_time Interacting Components”, IST-2001-37167 (2002-2003) investigated QoS management methods for home networks.</p>

<b>Team Leader</b>	
	<p>Prof. Michael González Harbour                      Universidad de Cantabria  <a href="http://www.ctr.unican.es">http://www.ctr.unican.es</a></p>
Technical role(s) within ArtistDesign	<p>The role of University of Cantabria is to provide support for schedulability analysis of embedded distributed systems with real-time requirements. The Group has also developed methodologies and tools for software engineering of real-time systems in which a mixture of soft and hard deadlines can be found and as such is leading the activity on Flexible Scheduling Technologies. The group is also actively participating in the development of the Real-time POSIX operating systems standards, and is active in real-time languages, (Ada) and therefore contributing to the platform being used in the Real-Time Languages activity.</p> <p>One important goal of the Group has always been to test the results of basic research in practical applications. As a consequence, the Group has contacts with industrial companies in the field of industrial automation.</p>
Research interests	Real-Time Schedulability Analysis, Real-Time Operating Systems, Real-Time Languages, Real-Time networks
Role in leading conferences/journals/etc in the area	Program chair of ECRTS 07, Program Co-Chair of the International Conference on Reliable Software Technologies 2006, Program Committee Member of RTAS, RTSS, ECRTS, and various Workshops on real-time systems.
Notable past projects	FRESCOR, Framework for Real-time Embedded Systems based on COntRacts. The FRESCOR project is aimed at developing a framework that integrates advanced flexible scheduling techniques directly into an embedded systems design methodology, covering all the levels involved in the implementation, from the OS primitives, through the middleware, up to the application level <a href="http://www.frescor.org">www.frescor.org</a>

<b>Team Leader</b> <b>Activity Leader for “Real-Time Networks”</b>	
	<p>Prof. Luis Almeida                      University of Porto                      URL: <a href="http://www.fe.up.pt/~lda/">http://www.fe.up.pt/~lda/</a></p>

Technical role(s) within ArtistDesign	Leader of the team from the University of Porto.
Research interests	Real-time communication (traffic scheduling, protocols,...) Flexible architectures for distributed embedded systems
Role in leading conferences/journals/etc in the area	Member of the IEEE Tech Committee on Real-Time Systems, Vice-President of the RoboCup Federation Has chaired several conferences/workshops (e.g., RTSS, RTN, WTR, WiP sessions). Reviewer for several related journals (e.g., IEEE TII, TIE, TC, ACM TECS, Springer JRTS – Assoc. Ed.)
Notable past projects	iLAND -mlldLewAre for deterministic dynamically reconfigurable Networked embedded systems (ARTEMIS) – team leader <a href="http://www.iland-artemis.org/">http://www.iland-artemis.org/</a> HaRTES: Hard Real-Time Ethernet Switching (FCT) – co-PI <a href="http://www.ieeta.pt/lse/hartes/">http://www.ieeta.pt/lse/hartes/</a> ARTIST2 (FP6 NoE) – team leader CAMBADA – Cooperative Autonomous roBoTs with Advanced Distributed Architecture (participant). <a href="http://www.ieeta.pt/atri/cambada/">http://www.ieeta.pt/atri/cambada/</a> ARTIST (FP5 accompanying measure) – team leader.
Awards	Best Paper Award in ETFA 2008 Best Work-in-Progress Paper Award in WFCS 2008 Best Paper Award in ANIPLA 2006 Best Paper Award in WFCS 2004 Best Paper Award in SICICA 2000

<b>Team Leader</b>	
	Prof. Eduardo Tovar Polytechnic Institute of Porto (ISEP-IPP), Porto (Portugal) URL: <a href="http://www.hurray.isep.ipp.pt/asp/show_people.asp?id=1">http://www.hurray.isep.ipp.pt/asp/show_people.asp?id=1</a>
Technical role(s) within ArtistDesign	The role of ISEP-IPP team is to investigate distributed embedded systems, with a particular focus on communication protocols for WSN and MANETs. The team is involved in flexible scheduling technologies, resource management policies and QoS-aware collaborative computing. The team has also a strong commitment in Real-Time Languages.

Research interests	Real-time systems, wireless sensor networks, multiprocessor platforms, communication networks, factory automation and system integration.
Role in leading conferences/journals/etc in the area	<p>Executive Board Member of the Euromicro Technical Committee on Real-Time Systems.</p> <p>Program Chair ECRTS'05, RTN'02, WDES'06.</p> <p>General Chair of WFCS'00, ECRTS'03.</p> <p>Program committee member in several editions of ERCTS, RTSS, RTAS, RTCSA, ICDCS, SRDS, WFCS, ETFA, EMSOFT and other IEEE, ACM and Euromicro events on real-time systems, embedded systems and factory communication systems.</p> <p>Reviewer for Real-Time Systems, IEEE Transactions on Computers, ACM Transactions on Embedded Computing, IEEE Transactions on Industrial Informatics.</p>
Notable past projects	<p>“REMPLI: Real-time Energy Management via Power-lines and Internet”, NNE5-2001-00825 (2003-2006) investigated advanced scheduling and protocols for power-line communication systems (PLC).</p> <p>“R-Fieldbus: High Performance Wireless Fieldbus in Industrial Multimedia-Related Environment”, IST-1999-11316 (2001-2003), integrated advanced real-time mechanisms in hybrid wired/wireless fieldbus networks. Mobility protocols and end-to-end deadlines..</p> <p>“CABERNET: Network of Excellence in Distributed Computing Systems Architectures”, IST-2000-25088 (2001-2003).</p> <p>“CIDER: Communication Infrastructure for Dependable Evolvable Real-time systems”, POSI/1999/CHS/33139 (2001-2003), Portuguese Science Foundation project on real-time communication networks.</p>
Further Information	Senior Member of IEEE

<b>Team Leader</b> <b>Activity Leader for “Design for Adaptivity”</b>	
	<p>Professor Karl-Erik Årzén            Lund University            URL: <a href="http://www.control.lth.se/user/karlerik/">http://www.control.lth.se/user/karlerik/</a></p>
Technical role(s) within ArtistDesign	Leader for the Transversal activity “Design for Adaptivity”. Team leader for Lund University. Participates in the OS and Networks cluster
Research interests	Embedded control, real-time systems, adaptive resource management, veeback applied to computer systems
Role in leading conferences/journals/etc in the area	CoChair 4th Intl. Workshop on Feedback Control Implementation and Design in Computing Systems & Networks (FeBID 2009)
Notable past projects	RUNES, ARTIST2, ACTORS (ongoing)
Awards	The Dr Guido Carlo-Stella award in manufacturing automation from the World Batch Forum in 2006 for achievements in manufacturing automation and information structuring

<b>Team Leader</b>	
	<p>Prof. Dr. Maja D'hondt            IMEC vzw.  <a href="http://www.imec.be">http://www.imec.be</a></p>
Technical role(s) within ArtistDesign	<p>Representing IMEC Smart Systems and Energy Technology division in:</p> <ul style="list-style-type: none"> <li>-Cluster: SW Synthesis, Code Generation and Timing Analysis</li> <li>-Cluster: Operating Systems and Networks</li> <li>-Cluster: Hardware Platforms and MPSoC Design</li> <li>-Intercluster activity: Design for Adaptivity</li> <li>-Intercluster activity: Integration Driven by Industrial Applications</li> </ul>

<p>Research interests</p>	<p>Maja D'Hondt received her Master and Ph.D degrees in Computer Science from the Vrije Universiteit Brussel in Belgium in 1998 and 2004 respectively. Since 2008 she leads a team of (senior) researchers and PhD students working on run-time resource management middleware for embedded systems.</p>
<p>Role in leading conferences/journals/etc in the area</p>	<p>Maja D'Hondt has published in International Journals and Conferences. She has sat on several program committees of international conferences. She played an active role in the organization of international conferences as workshop and tutorial chair.</p>
<p>Notable past projects</p>	<p>Responsible for Scalopes ARTEMIS project              (<a href="http://www.scalopes.eu/">http://www.scalopes.eu/</a>), OptiMMA IWT project              (<a href="http://www.imec.be/OptiMMA">www.imec.be/OptiMMA</a>), and Stadium IWT project              (distrinet.cs.kuleuven.be/projects/stadium/).</p>

#### 4.2 Affiliated Industrial Partners

<b>Team Leader</b>	
	<p>Dr. Paolo Gai (Ph.D.)            Evidence srl (Italy)            URL: <a href="http://feanor.sssup.it/~pj/">http://feanor.sssup.it/~pj/</a></p>
Technical role(s) within ArtistDesign	Support for the SHaRK kernel maintenance, consulting on POSIX and OSEK standards, real-time kernels, design and analysis tools.
Research interests	Real-time scheduling, operating systems, design and analysis tools.
Notable past projects	<p>FIRST: Flexible Integrated Real-time Systems Technology, IST-2001-32467 (2002-2005) investigated advanced scheduling for handling applications with various real-time requirements.</p> <p>OCERA: Open Components for Embedded Real-time Applications, IST-2001-35102 (2002-2005) integrated advanced real-time mechanisms in open-source kernels.</p> <p>ARTIST: Advanced Real-Time Systems.  <a href="http://www.artist-embedded.org">http://www.artist-embedded.org</a></p>

#### 4.3 Affiliated Academic Partners

<b>Team Leader</b>	
	<p>Prof. Marisol García-Valls            Universidad Carlos III de Madrid            URL: <a href="http://www.it.uc3m.es/mvalls">http://www.it.uc3m.es/mvalls</a></p>
Technical role(s) within ArtistDesign	UC3M leader on Adaptive resource management for CE"
Research interests	<p>Distributed systems: real-time middleware and communications.            QoS-based resource management and multimedia.            Scheduling.            Real-time languages (real-time Java, Ada DSA)</p>

Role in leading conferences/journals/etc in the area	<p>Participation in the Programme Committee of conferences such as ETFA, ICESS, EstiMedia.</p> <p>Reviewer of a number of Journals: Trans. Industrial Informatics, Trans. Industrial Electronics, Real Time Systems Journal, Concurrency Practice and Experience, etc.</p>
Notable past projects	<p>iLAND (Technical coordinator/leader): mIddLewAre for deterministic dynamically reconfigurable Networked embedded systems (ARTEMIS-JU 100026). From 2009 to 2012</p> <p>DDS Gateway for web services.</p> <p>ARTISTDesign, ARTIST2</p> <p>ARTIST: Advanced Real-Time Systems.</p>

<b>Activity Leader for “Qos-aware components”</b>	
	<p>Prof. Alejandro Alonso</p> <p>Universidad Politécnica de Madrid.</p> <p>URL: <a href="http://www.dit.upm.es/aalonso">http://www.dit.upm.es/aalonso</a></p>
Technical role(s) within ArtistDesign	<p>Activity Leader for “Qos-aware components”</p> <p>UPM leader on Adaptive resource management for CE”</p>
Research interests	<p>Design of real-time systems, programming languages, scheduling, distributed systems and quality of service</p>
Role in leading conferences/journals/etc in the area	<p>Participation in the Programme Committee of conferences such as Euromicro Real-Time Systems, International Conference on Reliable Software Technologies.</p>
Notable past projects	<p>MORE: Network-centric Middleware for GrOup communication and Resource Sharing across Heterogeneous Embedded Systems</p> <p>HIJA: High-Integrity Java Applications. The goal is to develop a new Java-based middleware platform fo the creation of Architecture-Neutral, high-integrity, distributed Real-Time Systems (ANRTS)</p> <p>ROBOCOP and Space4U. Development of component framework for embedded devices. It includes support for QoS and resource management.</p> <p>TRECOM: Techniques for the development of advanced distributed real-time systems for safety and business critical systems.</p>

<b>Team Leader</b>	
	Prof. Hermann Härtig Dresden University of Technology URL: <a href="http://os.inf.tu-dresden.de/~haertig/">http://os.inf.tu-dresden.de/~haertig/</a>
Technical role(s) within ArtistDesign	Virtualisation, microkernels, real-time operating systems.
Research interests	Real-time operating systems for the support of applications with Quality of Service requirements. Scheduling and file system support for bounded response time.
Role in leading conferences/journals/etc in the area	Program Committee member Reviewer
Notable past projects	Fiasco, L <sup>4</sup> Linux, L4Env

<b>Team Leader</b>	
	Name: Alfons Affiliation: Universidad Politécnica de Valencia, Spain URL: <a href="http://www.gii.upv.es/personal/alfons/">http://www.gii.upv.es/personal/alfons/</a>
Technical role(s) within ArtistDesign	Real-time control on embedded platforms
Research interests	Virtualisation, hypervisor, real-time operating system, dynamic memory management
Role in leading conferences/journals/etc in the area	Program Committee member Reviewer
Notable past projects	ARTIST2: Network of Excellence on Embedded Systems Design. U.E. IST Programme - IST 004527. 2004-08 FRESCOR: Framework for Real-time Embedded Systems based on COnT Racts FRESCOR. U.E. IST Programme - IST 034026. 2006-

	<p>2009</p> <p>THREAD: Integral support for embedded, distributed open real-time systems Spanish Ministry of Education, Science and Technology - TIC2005-08665-C03. 2005-2008</p> <p>SENSE: Smart Embedded Network of Sensing Entities. U.E. IST Programme - IST 033279. 2006-2009</p> <p>TECOM: Trusted Embedded Computing. Programme ITEA-2 and PROFIT (M. Industria, Spanish Government). 2007-2010</p> <p>OCERA: Open Components for Embedded Real-Time Applications. U.E. IST Programme (IST 35102). 2002-05</p>
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<b>Team Leader</b>	
	<p>Prof. Jean-Dominique Decotignie                      Ecole Polytechnique Fédérale de Lausanne (Switzerland)                      URL: <a href="http://lamspeople.epfl.ch/decotignie/">http://lamspeople.epfl.ch/decotignie/</a></p>
Technical role(s) within ArtistDesign	
Research interests	
Role in leading conferences/journals/etc in the area	
Notable past projects	

<b>Team Leader</b>	
	<p>Prof. Lucia Lo Bello                      University of Catania (Italy) – Affiliated to SSSA, Pisa                      URL: <a href="http://www.diit.unict.it/users/llobello/">http://www.diit.unict.it/users/llobello/</a></p>
Technical role(s) within ArtistDesign	<p>Support for the SHaRK kernel maintenance. Implementation of industrial multimedia system using SHARK. Execution time measurement.</p> <p>Stochastic analysis of soft real-time tasks in the context of priority-driven soft real-time systems. Calculation of stochastic response time profiles of tasks that are hierarchically scheduled using server based techniques.</p>

	<p>Support for real-time communication in distributed embedded systems, with particular reference to networked embedded systems used in factory communication and in automotive environments.</p> <p>Real-time communication over wireless networks: modeling, timing analysis, transmission scheduling, topology management, coexistence assessments, to support soft real-time traffic over IEEE 802.11, 802.15.4 and Bluetooth networks.</p> <p>Design issues and protocols for wireless sensor networks and networked embedded systems.</p>
Research interests	<p>Wireless networks and sensor networks, factory communication, real-time scheduling, overload handling, real-time industrial embedded systems, networked embedded systems, energy-aware protocols, automotive communications.</p>
Role in leading conferences/journals/etc in the area	<p>Program Chair of SOCNE 2010, HSI'09, ETFA 08, ETFA 05.</p> <p>WIP Chair of ETFA 09, SIES 07, ETFA 06.</p> <p>General Chair of ECRTS 04.</p> <p>On the PC of many editions of ECRTS, RTSS, RTAS, WFCS, ETFA, RTN , FET, RTNS, WTR.</p> <p>Reviewer for several international journals, included the Real-Time Systems Journal, IEEE/IES Transactions on Industrial Informatics, IEEE Transactions on Industrial Electronics, ACM Transactions on Embedded Systems, IEEE Transactions on Education.</p> <p>On the Editorial Board of the Journal of Real-time Image Processing, Springer, Germany.</p>
Notable past projects	<p>Italian National projects</p> <p>PRIN 04 entitled "Study and development of a real-time land control and monitoring system for fire prevention",</p> <p>COFIN 01 entitled "High-Performance Processing for Applications with High-Intensity Computational Requirements and Real-Time Constraints,</p> <p>both funded by the Italian Ministry of University and Research</p> <p>European project ESPRIT 26951 "NOAH - Network Oriented Application Harmonization.</p>
Further Information	<p>Responsible for the University of Catania of the flexWARE Project, Flexible Wireless Automation in Real-Time Environments, <a href="http://www.flexware.at">www.flexware.at</a>, a STREP Project funded by the European Commission within the 7 FP.</p> <p>Involved in standardization activities as Member of the International Electrotechnical Commission (IEC), Technical Committee SC65C, as member of</p> <ul style="list-style-type: none"> <li>Working Group 16, dealing with Wireless Industrial communication networks.</li> <li>Working Group 17, dealing with Coexistence in Wireless Industrial communication networks.</li> <li>Working Group 11, Real-Time Industrial Ethernet (RTE).</li> </ul> <p>Senior member of the IEEE since June 2009.</p> <p>Recipient of the IEEE Industrial Electronics Society 2008 Early Career Award.</p>

<b>Team Leader</b>	
	Dr. Pau Martí Technical University of Catalonia, Barcelona, Spain URL: <a href="http://www.upcnet.es/~pmc16/">http://www.upcnet.es/~pmc16/</a>
Technical role(s) within ArtistDesign	Real-time systems and control systems co-design
Research interests	Real-time and control systems, overload handling, jitter analysis and compensation, control theory.
Role in leading conferences/journals/etc in the area	Program committee member of major real-time and control conferences. Reviewer for the Real-Time Systems Journal.

<b>Team Leader</b>	
	Prof. Tullio Facchinetti Robotic Lab, University of Pavia, Italy URL: <a href="http://robot.unipv.it/toolleeo/">http://robot.unipv.it/toolleeo/</a>
Technical role(s) within ArtistDesign	Provide support for the development of real-time control applications in the domain of robotics and automation.
Research interests	Sensory systems, robotics applications, wireless communication, energy-aware computing.
Role in leading conferences/journals/etc in the area	Program committee member of major conferences on robotics. Reviewer of International journals on robotics. Member of the evaluation committee for national projects.

<b>Team Leader</b>	
	Prof. Julian Proenza University of the Balearic Islands URL: <a href="http://dmi.uib.es/research/SRV/jpa_ppl_en.htm">http://dmi.uib.es/research/SRV/jpa_ppl_en.htm</a>
Technical role(s) within	Team leader of affiliated partner. Indirect participation in the Cluster,

ArtistDesign	with the core team University of Porto.
Research interests	Dependable and Real-Time Systems, in particular, on fault-tolerant distributed systems, clock synchronization and field-bus networks, like CAN (Controller Area Network).
Role in leading conferences/journals/etc	Chair of several workshops in his fields of interest. Participation in several Organizing and Program Committees of related events.

<b>Team Leader</b>	
	Prof. Paulo Pedreiras University of Aveiro URL: <a href="http://www.ieeta.pt/~pedreiras">http://www.ieeta.pt/~pedreiras</a>
Technical role(s) within ArtistDesign	Team leader of affiliated partner. Indirect participation in the Cluster, with the core team University of Porto
Research interests	Distributed Real-Time Systems, in particular, real-time communication protocols and operating systems, low level QoS management.
Role in leading conferences/journals/etc in the area	Participation in several Organizing and Program Committees of related events for several years.

<b>Team Leader</b>	
	Prof. Sverre Hendseth Norwegian University of Science and Technology, Trondheim (NTNU) URL: <a href="http://www.itk.ntnu.no/ansatte/Hendseth_Sverre/">http://www.itk.ntnu.no/ansatte/Hendseth_Sverre/</a>
Technical role(s) within ArtistDesign	Team leader of affiliated partner. Indirect participation in the Cluster, with the core team Scuola Superiore Sant'Anna, Pisa
Research interests	Distributed Real-Time Systems, real-time communication protocols and concurrent languages.
Role in leading conferences/journals/etc in the area	Participation in several Organizing and Program Committees of related events for several years.

#### 4.4 Affiliated International Partners

	<p>Professor John Stankovic, University of Virginia                  URL: <a href="http://www.cs.virginia.edu/people/faculty/stankovic.html">http://www.cs.virginia.edu/people/faculty/stankovic.html</a></p>
<p>Technical role(s) within ArtistDesign</p>	<p>Technical expert.</p>
<p>Research interests</p>	<p>Real-time computing, cyber physical systems, wireless sensor networks, and wireless energy and health applications.</p>
	<p>Professor Lui Sha, University of Illinois at Urbana-Champaign  <a href="http://www.cs.uiuc.edu/directory/directory.php?name=sha">http://www.cs.uiuc.edu/directory/directory.php?name=sha</a></p>
<p>Technical role(s) within ArtistDesign</p>	<p>Technical expert.</p>
<p>Research interests</p>	<p>Distributed real-time computing systems, dynamic real-time architecture, QoS driven resource management and security and fault tolerance in networked embedded systems.</p>

	<p>Professor Tarek Abdelzaher, University of Illinois at Urbana-Champaign  <a href="http://www.cs.uiuc.edu/homes/zaher/">http://www.cs.uiuc.edu/homes/zaher/</a></p>
<p>Technical role(s) within ArtistDesign</p>	<p>Technical expert</p>
<p>Research interests</p>	<p>Operating systems, networking, sensor networks, distributed systems, and embedded real-time systems.</p>

	<p>Professor Marco Caccamo, University of Illinois at Urbana-Champaign  <a href="http://pertsserver.cs.uiuc.edu/~mcaccamo/">http://pertsserver.cs.uiuc.edu/~mcaccamo/</a></p>
<p>Technical role(s) within ArtistDesign</p>	<p>Technical expert</p>
<p>Research interests</p>	<p>Real-time systems, real-time scheduling and resource management, wireless real-time networks, and quality of service control in next generation digital infrastructures.</p>

	<p>Professor Sanjoy Baruah, University of North Carolina at Chapel Hill  <a href="http://www.cs.unc.edu/~baruah/">http://www.cs.unc.edu/~baruah/</a></p>
<p>Technical role(s) within ArtistDesign</p>	<p>Technical expert.</p>
<p>Research interests</p>	<p>Schedulability analysis and multiprocessor systems.</p>

## 5. Internal Reviewers for this Deliverable

- **Sanjoy Baruah** (University of North Carolina at Chapel Hill)
- **Marco Caccamo** (University of Illinois at Urbana Champaign)