IST-004527 ARTIST2
Network of Excellence
on Embedded Systems Design

Cluster Progress Report for Year 4

Cluster:
Adaptive Real Time

Cluster Leader:

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Policy Objective (abstract)

The objective of the cluster is to provide support to emerging applications (e.g., multimedia systems, robotics, telecommunications) characterized by reactive behaviors in highly dynamic environments. Achieving adaptivity in embedded real-time systems is a complex task that requires expertize from several disciplines, including operating systems, scheduling theory, network communication, control theory, quality of service management, and programming languages. To cover these issues, the ART cluster is organized into 5 activities:

1. JPIA Platforms: A common infrastructure for adaptive real-time systems
2. JPRA NoE: QoS Aware Components
3. JPRA Cluster: Flexible Resource Management
4. JPRA Cluster: Dynamic and Pervasive Networking
5. JPRA Cluster: Real-Time Languages

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1. Overview

1.1 High-Level Objectives

This section is the same with respect to the previous year because the high-level objectives of the cluster did not change.

The high level objective of the ART cluster was to build the fundamental bases 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 and dynamic behavior. 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 of embedded systems;
- increase programming flexibility, for specifying functional and performance requirements to simplify test and verification;
- increase system adaptivity to react to environmental changes, still providing a sufficient level of performance;
- be robust to tolerate transient and permanent overloads conditions due to wrong design assumptions or unpredictable changes.

All these objectives have been achieved by the cluster and had a concrete impact on European industry to reduce time to market and improve software realiability and testabilty. To support industry in such a transition phase, new tools, algorithms and kernel mechanisms have been provided. In this respect, the ART cluster played an active role, acting as a bridge between the academic and the industrial world, especially in the domain of consumer electronics, robotics, and telecommunications.

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

1.2 Industrial Sectors

This section is the same with respect to the previous year because the industrial sectors that can benefit from the research carried out by the ART Cluster did not change.

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. Mainly driven by Moore's law, the evolution in the CE industry is very fast [Bou05]. Utilizing available hardware and software resources in an optimal fashion is crucial both to save costs and to keep the competitive edge. Moreover, multimedia systems exhibit a highly dynamic behavior, since task execution times are often

dependent on input data that are difficult to predict [Riz06]. As a consequence, these systems are prone to intermittent overload conditions that could degrade the performance in an unpredictable fashion [Wus05, Loo03]. To address these problems, the ART 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. This imposes a continuous increment in processing power and memory capacity that requires adaptivity at different levels of system operation. The contribution of the ART 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 referred systems are microprocessor based platforms, often integrating a second processor (e.g., a DSP) devoted to specific functions, like MPEG coding. From the software point of view, a modern mobile phone typically consists of several million lines of code with use-cases involving large number of concurrent activities. A system supporting ``memory and temporal protection'' would allow safely mixing real-time and non real-time applications with the benefit of achieving a more scalable platform. The work on resource reservation carried out in the ART cluster was of crucial importance to manage the increased complexity of the applications in this domain.

1.3 Main Research Trends

During their evolution, embedded systems became more and more dynamic in terms of resource requirements, making the computational load to be hardly predicted in advance. The combination of real-time features in dynamic environments, together with cost and resource constraints, created new problems to be addressed in the design of such systems, at different levels of the architecture. Moreover, the development of multi-core platforms introduced an additional degree of complexity, requiring new methodologies for designing software, performing feasibility analysis, and achieving efficient allocation and scheduling of the application tasks.

To cope with dynamic resource requirements, a system 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 [Loo03, Eke05]. Implementing adaptive embedded systems requires specific support at different levels of the software architecture. The most important component affecting adaptiveness is the kernel, hence specific research efforts are being devoted to flexible, as well as predictable real-time scheduling and resource management policies [But06]. However, flexibility can also be introduced above the operating system, in a software layer denoted as a middleware. To investigate such a possibility, other research groups are working on this level to introduce adaptivity and QoS management [Sch03, Wan05, Sch06, Gar02].

There are cases in which embedded systems are large and distributed among several computing nodes. In these cases, special network methodologies are needed to achieve adaptive behavior and predictable response [Alm03] [Ped05]. Several research efforts have also been placed in addressing wireless sensor networks (WSN) [Sta03], mobile ad-hoc networks MANET [Joh96, Wu04, Fac05] and other networked systems for which, albeit the dynamic nature and resource scarcity of the infrastructure, timeliness is still a requirement.

2. State of the Integration in Europe

2.1 Brief State of the Art

Modern computer architectures include several low-level mechanisms that are designed to enhance the average performance of applications, but unfortunately introduce high variations on tasks' execution times. In other situations, as in multimedia systems, processes can have highly variable execution times that also depend on input data [Riz06]. As a consequence, the overall workload of a computing system is subject to significant variations, which can produce an overload and degrade the performance of the entire system in an unpredictable fashion [Loo03, Eke05]. For most of these systems, the classical real-time approach based on a rigid off-line design, worst-case assumptions and a priori guarantee would keep resources unused for most of the time, therefore it is not acceptable for efficiency reasons. When resources are scarce, they cannot be wasted. On the other hand, an off-line design based on average-case behavior is also critical, because it would be difficult to guarantee timing constraints when resources are overloaded.

To prevent unpredictable performance degradations due to overloads, a real-time system must react to load variations, degrading its performance in a controlled fashion acting on system, as well as application parameters. The process of controlling the performance of a system as a function of workload variations is referred to as Quality of Service (QoS) Management. Performing efficient QoS management requires specific support at different levels of the system architecture. Hence, new software methodologies are emerging in Embedded Systems, which strictly relate to Real-Time Operating Systems (RTOS), Middleware, and Networks. Major needs for flexible scheduling techniques are typical of industries working in consumer electronics, industrial automation, and telecommunications, as resulted from a study carried out within the ARTIST 5FP project [Bou05].

The scheduler is the mechanism having the most significant impact on the performance of a real-time kernel. Most scheduling algorithms have been developed around one of three basic schemes: table driven [Foh95], fixed priority [Aud95], or dynamic priority [Spu96, Bin07]. Depending on whether scheduling decisions are resolved before or during runtime, they are classified as offline or online. Adapting to changing environmental situations may involve changes to task parameters at runtime. System wide changes, e.g., for changing operational modes in the system, have been addressed by mode change algorithms [Foh93]. Feedback control scheduling applies control theory to estimate the effects of changes and to choose parameters to avoid instability and achieve smooth responses [Cas06, Hoa07].

For embedded systems consisting of multiple components, hierarchical scheduling [Reg01, Lip05] is an effective techhique to arbitrate between a set of diverse scheduling algorithms. According to this scheme, the amount of the CPU portion can be set individually for each scheduler and application.

For embedded systems subject to higly varialble workload, an overload condition could degrade the system performance in an unpredictable fashion. Novel scheduling methodologies have been recently proposed to cope with transient and permanent overload conditions [BMV07]. Transient overloads due to execution overruns can be effectively handled using resource reservation techniques [Mer94], according to which each activity consumes a fraction of the processing resource, independently of the actual execution demand. Permanent overload conditions, typically occurring in a periodic environment, can be efficiently handled by sporadic job skipping [Kor95] or by rate adaptation techniques (like elastic scheduling) [But02], which keep the load below a given threshold by acting on task periods.

2.2 Main Aims for Integration and Building Excellence through Artist2

This section is the same as the previous year because the aims for integration and building excellence through Artist2 did not change.

Achieving adaptivity in embedded real-time systems is a complex task that requires expertize from several disciplines, including operating systems and kernels, scheduling theory, distributed systems, network communication, control theory, quality of service management, and programming languages. Combining the results achieved in such different domains and orchestrating the various groups active in these fields is only possible by a tight interaction among the cluster participants. Hence, the aim of the integration through Artist2 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.

2.3 Other Research Teams

This section is the same as the previous year because the other research teams interacting with the cluster did not change.

The ART cluster had several interactions with the following research teams:

- University of Illinois at Urbana Champagne (reference persons: Prof. Lui Sha, Prof. Tarek Abdelzaher, and Prof. Marco Caccamo) on wireless communication protocols for real-time distributed emebedded 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 tecniques for adaptive real-time systems.
- University of California at Berkeley (reference person: Alberto Sangiovanni Vincentelli) on the design of component-based operating systems.
- ARTIST2 cluster on Modelling and Components, for modelling, composition, and verification of timing properties.
- Philips Research Eindhoven (reference persons: Dr. Sjir 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.
- Carnagie-Mellon University (reference person: Prof. Raj Rajkumar) on wireless sensor networks, cooperative computing, andQoS 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.

2.4 Interaction of the Cluster with Other Communities

Interaction with the control community

The ART cluster had several interactions with the control community and in particular with the cluster on Control for Embedded Systems. Since the first year, the two cluster leaders, Giorgio Buttazzo (ART) and Karl-Erik Arzen (Control) organized a number of meetings and workshops to exchange ideas and propose more concrete actions to make progress in this area.

A joint work involving people from Pavia, Pisa and Lund has been carried out to integrate feedback control schemes into the Shark operating system (used as a shared platform) and to investigate the effects of different scheduling policies on delays and jitter in control loops.

Another strong collaboration has been established with the hybrid systems community. As a result of this connection, Giorgio Buttazzo has been invited as a co-Program Chair to organize the International Conference on Hybrid Systems: Computation and Control (HSCC 2007).

A joint work involving people from UPC (affiliated to TUKL) and Lund has been carried out to investigate feedback scheduling techniques. A PhD student from UPC spent 5 months in Lund working on the project.

In the last year, Pisa, Lund and TUKL started a collaboration to achieve adaptive resource reservations in multi-core systems. Pisa contributed to identify the most appropriate scheduling algorithms, Lund contributed on feedback control schemes, and TUKL on defining the programming interface.

Interaction with the cluster on compilers and timing analysis

A collaboration has been started with the cluster on compilers and timing analysis to investigate the problem of enhancing the predictability of real-time systems by reducing the variability of task execution times. In fact, internal kernel mechanisms, such as scheduling, mutual exclusion, interrupt handling and communication, can heavily affect task execution behaviour and hence the timing predictability of a system. For example, preemptive scheduling reduces program locality in the cache, increasing the worst-case execution time of tasks compared with non preemptive execution.

To address these issues, a new research was initiated that looks at predictability and efficiency in a synergistic manner and that involves all levels of abstraction and implementation in embedded-system design.

Thanks to the ARTIST2 network of excellence, the ART cluster got in contact with the cluster on Compilers and Timing Analysis. The two clusters started working together to develop a new

approach consisting of a combination of several methods, including (a) design-space exploration on the hardware architecture level to identify good designs offering combinations of strong performance with good predictability, (b) appropriate kernel mechanisms for task and resource management that are predictable and analyzable, and (c) a synergistic development of models, design methods and matching analysis tools that extract precise system-behaviour properties.

Interaction with the consumer electronics industry

Thanks to the International Collaboration Days organized within the ARTIST2 project, the ART cluster got in contact with two major companies, Philips and Ericsson, acting in the domain of consumer electronics. After a tight interaction with the engineers responsible for the software development process, a number of industrial needs have been identified, that would make new generation products more robust and flexible.

To cope with a constantly increasing complexity of software applications (already consisting of several million lines of code and hundreds of concurrent activities), a system supporting memory and temporal protection would allow safely mixing real-time and non real-time applications with the benefit of achieving a more scalable platform. Therefore, the work on resource reservation carried out within the ART cluster is of crucial importance to manage the increased complexity of the applications in this domain.

In addition, multimedia systems exhibit a highly dynamic behavior, since task execution times are often dependent on input data that are difficult to predict. As a consequence, these systems are prone to intermittent overload conditions that could degrade the performance in an unpredictable fashion. Again, the expertize existing in the ART cluster on overload management is of high interest for these companies, since it allows building flexible as well as predictable real-time systems that can react to load changes and perform QoS adaptation in a controlled fashion.

Interaction with the electronics industry

A new interaction of the ART cluster with Microchip Technology has been started on real-time embedded platforms for monitoring and control. In particular, the expertize existing in the ART cluster on real-time embedded control applications and real-time operating systems is extremely actractive for Microchip, who is interested in pushing the development of real-time embedded applications using 16-bit microcontrollers (as the dsPIC30 and the dsPIC33).

In this context, a big opportunity for the ART cluster is to find an agreament with Microchip to define the characteristics of a small real-time embedded platform for sensory acquisition and motor control that can be used (in conjunction with a wireless card) as a node of a mobile wirelss network. This unit would be more powerful and flexible than a mote and could be used to carry out experiments on sensor networks, embedded control, mobile robot teams and distributed control systems.

Interaction with the language community

The ART cluster participated in the development of Ada, (Ada 2005), Java (RTSJ) and POSIX (for use with C and C++). This participation has included membership of the associated standardisation bodies that linked the work within the cluster with international efforts across such languages.

Interaction with the real-time components community

A collaboration between the clusters on components and adaptive real-time has been carried out along the ARTIST2 project. The main goal is to provide support for dealing QoS aspects in component-based systems. This 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 collaboration between those clusters has brought competencies in component-based design for hard and adaptive real-time systems, to produce advances that would be difficult to achieve without all three.

This cooperation has facilitated the development of a number of technical achievents along four research lines: a) specification of QoS properties using UMNL profiles and aspect-based approachs, b) generation of analyzable models from the UML models, c) composition of QoS-aware components and adaptability, and d) QoS support in run-time components frameworks. The participants in this activity have actively participated in the development of a number of OMG standards

Dissemination

The ART cluster has been quite active in disseminating the research results achieved in the context of the ARTIST2 network of excellence, as an overall strategy for reaching other research/academic/industrial communities with related interests.

The operating system platform developed in the context of the Joint Programme of Integration Activities (JPIA) has been extensively used in summer schools and graduate courses to teach how to develop embedded applications with real-time and performance requirements.

In additions, several scientific papers have been published and a number of workshops, conferences, and invited talks have been organized by the ART cluster to spread the acquired knowledge in the scientific community. The conferences and workshops in which the ART cluster has been involved include:

- OSPERT 2008: Workshop on Operating Systems Platforms for Embedded Real-Time applications, Prague, Czech Republic, July 1, 2008.
- ETFA 2007: IEEE International Conference on Emerging Technologies and Factory Automation, Patras, Greece, September 25-28, 2007.
- RTSS 2007: IEEE Real-Time Systems Symposium, Tucson, Arizona, USA, December 3-6, 2007.
- ECRTS 2008: Euromicro Conference on Real-Time Systems, Prague, Czech Republic, July 2-4, 2008.
- RTAS 2008: IEEE Real-Time and Embedded Technology and Applications Symposium, St. Louis, MO, United States, April 22-24, 2008.
- HSCC 2007: ACM International Conference on Hybrid Systems: Computation and Control, Pisa, Italy, April 3-5, 2007.
- RTCSA 2008: IEEE International Conference on Embedded and Real-Time Computing Systems and Applications, Kaohsiung, Taiwan, August 25-37, 2008.
- IFAC 2008 World Congress, Seoul, Korea July 6-11, 2008.
- IECON 2007: Annual Conference of the IEEE Industrial Electronics Society, Taipei, Taiwan, November 5-8, 2007.
- WFCS 2008: IEEE International Workshop on Factory Communication Systems, Dresden, Germany, May 20-23, 2008.
- RTN 2008: International Workshop on Real Time Networks, Prague, Czech Republic, July 1, 2008.

- WPDRTS 2008: International Workshop on Parallel and Distributed Real-Time Systems (In conjunction with IPDPS), Miami, Florida, USA, April 14, 2008.
- Ada Europe 2008: International Conference on Reliable Software Technologies, Venice, Italy, June 16-20, 2008.
- ISORC 2008: IEEE International Symposium on Object and component-oriented Real-time distributed Computing, Orlando, Florida, USA, May 5-7, 2008.
- WTR 2007: Brazilian Workshop on Real-Time Systems, Belem, Brazil, May 28th, 2007.
- RTNS 2007: Int. Conf on Real-Time and Networked Embedded Systems, Nancy, France, March 29-30, 2007.
- SAE 2008 World Congress, Detroit, Michigan, USA, April 14-17, 2008.

Participation in Standards

The involvement of the ART cluster members in standardization activities did not change with respect to the previous year.

It includes the following activities:

- UML Profile QoS and Fault Tolerance
  URL: http://www.artist-embedded.org/artist/UML-Profile-QoS-and-Fault.html
  Member: Miguel A. de Miguel, UP Madrid.

- Ada
  URL: http://www.artist-embedded.org/artist/UML-Profile-QoS-and-Fault.html
  Member: Alan Burns, Univ. of York.

- POSIX 1003
  URL: http://www.artist-embedded.org/artist/POSIX-IEEE-1003.html
  Member: Michael Gonzalez Harbour, Univ. of Catabria.

- MPEG Multimedia Middleware (M3W)
  URL: http://www.artist-embedded.org/artist/MPEG-Multimedia-Middleware-M3W.html
  Member: Alejandro Alonso, UP Madrid.

- ETHERNET powerlink
  URL: http://www.artist-embedded.org/artist/ETHERNET-Powerlink.html
  Member: Lucia Lo Bello, Univ. of Catania (affiliated to Pisa).

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3. Overall Assessment and Vision for the Cluster

3.1 Assessment for Year 4

The integration activities among the cluster participants has continued to progress also during the fourth year and is demonstrated by the number of joint publications, projects and events organized within the cluster. The main examples are our summer schools, graduate courses, and the various research consortia that have led to new European projects, like FRESCOR, ACTORS, and PREDATOR. The mobility between the partners has also increased compared to previous years.

In particular, a relevant result of the activity on a common infrastructure was the development of two operating system platforms: one for experimenting novel scheduling and resource management algorithms on PC architectures (Shark) and another for running real-time applications under severe resource constraints (Erika on the Flex board). Several control applications have been developed using such platforms, as reported in the corresponding deliverable, and are now available for the community for training and education.

From a more theoretical side, the activity on scheduling and resource management gave a substantial contribution to the development of the resource reservation framework, proposing a new programming paradigm based on quality-of-service contracts, allowing to abstract application requirements from implementation mechanisms.

The activity on languages produced a survey of current programming languages for embedded and real-time systems. This survey considers over twenty programming languages. All languages covered in the survey are implementation languages supported by tools (typically compilers) generating executable code for the designated hardware platform. To give a structure to the survey each language is placed in one of five classes: imperative, functional, synchronous, model-based, and platform-based. For real-time programming languages there are many such concepts that are supported to a greater or lesser extent in a range of languages that purports to be appropriate for the embedded systems domain. For example: time, clocks, concurrency, deadlines, events and signals, exceptions, periodicity, scheduling and predictability are all important notions that programmers may wish to address and which should therefore be available to them via the implementation languages that they can employ.

3.2 Overall Assesment since the start of the Artist2 NoE

The overall assessment of the work carried out by the cluster within these four years is very good. The major benefit of the ARTIST2 NoE was to act as a large scientific arena, where different research groups had the possibility to discuss, interact, and collaborate for addressing challenging research problems in the complex domain of embedded systems. Such a collaborative work produced the following significant results:

- Education. A number of summer schools, graduate courses, workshops and training laboratory activities have been organized to disseminate the knowledge of the cluster to graduate and PhD students.
- Challenging research issues. Different collaborations took place within the cluster that allowed exploiting complementary expertize 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.

- European projects. Several European projects started thanks to the integration activities triggered by ARTIST2. Examples are FRESCOR, ACTORS, PREDATOR, MORE, INTEREST, and INTERESTED.
- Bridge bewteen Industry and Academia. Several contacts with the industry have been established within ARTST2, which contributed to reduce the huge gap existing between the theoretical work carried out in the university and the applications developed by the companies. A significant effort has been made by the cluster to precisely define a common language between industry and academia.

The cluster has been involved in the standardisation activities surrounding a number of languages, including RTSJ (the Real-Time Specification for Java) and Ada (in particular the 2005 version), and OS standards such as POSIX (the Real-Time Profiles). The aim here has been to bring into industrial practice, via the languages employed to implement systems, the results of the research undertaken in scheduling and resource management. This takes the form of predictable concurrency features that allow hard real-time systems to be verified, and adaptive features that allows soft real-time QoS metrics to be optimised.

3.3 Vision Beyond the Artist2 NoE

The major result of the ART cluster has been to build a significant amount of knowledge on problems, methodologies, techniques, and tools for embedded systems with highly dynamic behavior. Such a knowledge is now available to be disseminated in the industry and in the academia to educate next generation engineers.

The vision beyond the ARTIST2 NoE is to organize such a huge amount of knowledge and make it available in different forms to help the development of embedded systems that are more robust, more efficient, more flexible, and more predictable than what is possible today.

Part of this cluster will continue to work within the ArtistDesign NoE, both in the OS and Networks domain, and in the transversal Design for Adaptivity activity. A lot of the work will also continue in the different existing and new IP and STREP projects that the core partners are members, e.g., FRESCOR, ACTORS, PREDATORS and INTERESTED, as well as in different national projects.

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.

4. Cluster Participants

4.1 Core Partners

Cluster Leader **Activity Leader for "NoE Integration: Low Power"**	
	Prof. Giorgio Buttazzo Scuola Superiore Sant'Anna (SSSA), Pisa (Italy) URL: http://feanor.sssup.it/~giorgio/
Technical role(s) within Artist2	Coordinating the ART cluster and the JPIA-Platform activity entitled "A Common Infrastructure for Adaptive Real-time 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. "OCERA: Open Components for Embedded Real-time Applications", IST-2001-35102 (2002-2005) integrated advanced real-time mechanisms in open-source kernels. "FABRIC: Federated Applications Based on Real_time Interacting Components", IST-2001-37167 (2002-2003) investigated QoS management methods for home networks.

	"ARTIST: Advanced Real-Time Systems", IST-2001-34820 (2002-2005) investigated adaptive real-time systems for QoS management. "TRACS - Flexible Real-Time Architecture for Traffic Control Systems", ESPRIT III project No. 6373 (1992-1995) investigated real-time techniques for vessel control systems.
Awards	Best paper Award at the 10th 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". Award for the best paper and presentation at the ANIPLA Workshop on Operating Systems for Industrial Control Applications, Milan, November 18, 1999. HUSPI Award given by Honeywell for the best journal publication on robotic systems, November 1987.
Further Information	Senior Member of IEEE

Team Leader **Activity Leader for "Real-Time Languages"**	
	Professor Alan Burns University of York, UK URL: www.cs.york.ac.uk/~burns
Technical role(s) within Artist2	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 Collabroations – A large, UK, 6-year, multisite project looking at dependability of computer-based systems. Burns was a PI and manged the work on temporal aspects of dependability. FIRST – EU funded project concerninf flexibile scheduling FRESCOR – EU follow on project to FIRST

Team Leader **Activity Leader for "Adaptive Resource Management for Consumer Electronics"**	
	Prof. Gerhard Fohler Technical Univeristy of Kaiserslautern (TUKL) URL: www.eit.uni-kl.de/fohler
Technical role(s) within Artist2	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.
Research interests	Real-time scheduling, integration of offline and online scheduling, QoS management, video streaming and media processing.
Role in leading conferences/journals/etc in the area	Chairman, technical committee on real-time systems, Euromicro Member of executive board technical committees on, IEEE real-time systems, IE embedded systems Area editor real-time, Journal of System Architecture, Elsevier Program chair, IEEE Real-Time Systems Symposium, 2006 Program chair, subtrack real-time systems, DATE 2005-2007 Program committee member of most real-time related conferences
Notable past projects	FRESCOR - Framework for Real-time Embedded Systems based on COntRacts, EU IST STREP WASP - Wirelessly Accessible Sensor Populations, EU IST IP BETSY - BEing on Time Saves energY continuous multimedia experience with low battery power, EU IST STREP FIRST - Flexible Integrated Real-Time System Technology, EU IST STREP FABRIC: "Federated Applications Based on Real_time Interacting Components", IST-2001-37167 (2002-2003) investigated QoS management methods for home networks.

Team Leader **Activity Leader for "Flexible Scheduling Technologies"**	
	Prof. Michael González Harbour Universidad de Cantabria http://www.ctr.unican.es/
Technical role(s) within Artist2	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. 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.
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 (www.frescor.org)

Team Leader	
	Prof. Luis Almeida University of Aveiro URL: http://www.ieeta.pt/lse

Technical role(s) within Artist2	Leader of the team from the University of Aveiro, participating in the ART cluster.
Research interests	Real-time communication (traffic scheduling, protocols,…) Flexible architectures for distributed embedded systems
Role in leading conferences/journals/etc in the area	Usually participates in the Organizing and /or Program Committees of conferences in the fields of Real-Time Systems (e.g., RTSS, ECRTS, RTAS) and industrial communications (e.g., WFCS, ETFA, FET). Has chaired several workshops (e.g., RTN, WTR, WiP sessions). Reviewer for several related journals (e.g., IEEE TII, TIE, TC, ACM TECS, Kluwer JRTS)
Notable past projects	ARTIST (FP5 accompaning measure). CAMBADA – Cooperative Autonomous roBots with Advanced Distributed Architecture. Specification and development of a team of cooperating autonomous robots for the Robocup Middle-Size Soccer League. Particular focus has been devoted to the architecture of each robot and their communication for information sharing. http://www.ieeta.pt/atri/cambada/ DISCO, DIStributed embeddable systems for COntrol applications. The objectives of the project were to investigate techniques and to develop solutions to improve flexibility and adaptability in distributed embedded control systems in order to reduce operation and maintenance costs while maximising the utilisation of system resources. http://www.ieeta.pt/lse/DISCO_web.pdf CIDER, Communication Infrastructure for Dependable and Evolvable Real-time systems. The project pursued two objectives: to analyse the usability of Ethernet in dependable applications (static set-up) and to devise the necessary mechanisms to allow the set-up to change dynamically (dynamic set of services and hosts) while providing the required dependability. http://www.hurray.isep.ipp.pt/activities/cider/
Awards	Best Paper Award in WFCS 2004 Best Paper Award in SICICA 2000

Team Leader	
	Professor Juan A. de la Puente Universidad Politécnica de Madrid URL: http://www.dit.upm.es/jpuente

Technical role(s) within Artist2	Team Leader of the Universidad Politécnica de Madrid, UPM leader on “Real-Time languages” and “Common infrastructure for Adaptive Real-Time Systems”
Research interests	Design of real-time systems, high-integrity systems, programming languages, scheduling, control systems and distributed systems
Role in leading conferences/journals/etc in the area	Associate editor of the Journal of Real-Time Systems. Participation in the Programme Committee of conferences such as Euromicro Real-Time Systems, International Conference on Reliable Software Technologies.
Notable past projects (optional – max 5)	ASSERT: Developmet of advance software techniques for high integrity systems for aerospace systems. TRECOM: Techniques for the development of advanced distributed real-time systems for safety and business critical systems. ORK (Open Ravenscar Real-TIme Kernel): Development of a kernel for safety-critical space systems.
Awards / Decorations	IFAC Fellow

Activity Leader for “Qos-aware components”	
	Prof. Alejandro Alonso Universidad Politécnica de Madrid. URL: http://www.dit.upm.es/aalonso
Technical role(s) within Artist2	Activity Leader for “Qos-aware components” UPM leader on Adaptive resource management for CE”
Research interests	Design of real-time systems, programming languages, scheduling, distributed systems and quality of service
Role in leading conferences/journals/etc in the area	Participation in the Programme Committee of conferences such as Euromicro Real-Time Systems, International Conference on Reliable Software Technologies.
Notable past projects	MORE: Network-centric Middleware for GrOup communication and Resource Sharing across Heterogeneous Embedded Systems 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) ROBOCOP and Space4U. Development of component framework for embedded devices. It includes support for QoS and resource management.

	TRECOM: Techniques for the development of advanced distributed real-time systems for safety and business critical systems.

Team Leader **Activity Leader for "Dynamic and Pervasive Networking"**	
	Prof. Eduardo Tovar Polytechnic Institute of Porto (ISEP-IPP), Porto (Portugal) URL: http://www.hurray.isep.ipp.pt/asp/show_people.asp?id=1
Technical role(s) within Artist2	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 leading the activity on Real-Time Networks and 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	Executive Board Member of the Euromicro Technical Committee on Real-Time Systems. Program Chair ECRTS'05, RTN'02, WDES'06. General Chair of WFCS'00, ECRTS'03. 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. Reviewer for Real-Time Systems, IEEE Transactions on Computers, ACM Transactions on Embedded Computing, IEEE Transactions on Industrial Informatics.
Notable past projects	"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). "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 neworks. Mobility protocols and end-to-end deadlines.. "CABERNET: Network of Excellence in Distributed Computing Systems Architectures", IST-2000-25088 (2001-2003).

	"CIDER: Communication Infrastructure for Dependable Evolvable Real-time systems", POSI/1999/CHS/33139 (2001-2003), Portuguese Science Foundation project on real-time communication networks.
Further Information	Senior Member of IEEE

4.2 Affiliated Industrial Partners

Team Leader	
	Dr. Paolo Gai (Ph.D.) Evidence srl (Italy) URL: http://feanor.sssup.it/~pj/
Technical role(s) within Artist2	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	FIRST: Flexible Integrated Real-time Systems Technology, IST-2001-32467 (2002-2005) investigated advanced scheduling for handling applications with various real-time requirements. OCERA: Open Components for Embedded Real-time Applications, IST-2001-35102 (2002-2005) integrated advanced real-time mechanisms in open-source kernels. ARTIST: Advanced Real-Time Systems. (http://www.artist-embedded.org)

4.3 Affiliated Academic Partners

Team Leader	
	Prof. Lucia Lo Bello University of Catania (Italy) – Affiliated to SSSA, Pisa URL: http://www.diit.unict.it/users/llobello/

Technical role(s) within Artist2	Support for the SHaRK kernel maintenance. Implementation of industrial multimedia system using SHARK. Execution time measurement. 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. Support for real-time communication in distributed embedded systems, with particular reference to networked embedded systems used in factory communication and in automotive environments. Real-time communication over wireless networks: modelling, timing analysis, and transmission scheduling to support soft real-time traffic over 802.11, 802.15.4 and Bluetooth networks. Design issues and protocols for wireless sensor networks and networked embedded systems.
Research interests	Real-time scheduling, overload handling, real-time communication protocols, factory communication, real-time communication over wireless networks, wireless sensor networks, automotive communications.
Role in leading conferences/journals/etc in the area	Program Chair of ETFA 05, ETFA 07. WIP Chair of ETFA 06. General Chair of ECRTS 04. PC member of many editions of ECRTS, RTSS;,RTAS,ETFA, WFCS, RTN , FET, RTNS ,WTR. Reviewer for the Real-Time Systems Journal, IEEE Transactions on Industrial Informatics, IEEE Transactions on Industrial Electronics, IEEE Transactions on Computers, Computer Standard and Interfaces, Journal of System Architectures. On the Editorial Board of the International Journal of Embedded Systems.
Notable past projects	Italian National project PRIN 04 entitled “Study and development of a realtime land control and monitoring system for fire prevention”, funded by the Italian Ministry of University and Research (http://www.prin.polito.it/) European project ESPRIT 26951 "NOAH - Network Oriented Application Harmonisation. Italian National COFIN 2001 inter-university project titled ‘’High-Performance Processing for Applications with High-Intensity Computational Requirements and Real-Time Constraints, funded by the Italian Ministry of University and Research (http://tsc.polito.it:7777/cofin2001/)
Further Information	Member of the International Electrotecnical Commission (IEC), Technical Committee SC65C, Working Group 11, Real-Time Industrial Ethernet (RTE), actively involved in standardization activities.

	Nominated expert member for the Italian Electrotechnical Committee (CEI-Comitato Elettrotecnico Italiano) in the Technical Committee SC65C “Digital Data Communications for Measurement and Control-Fieldbus for Use in Industrial Control Systems”, Maintenance Team 9, “High availability automation networks". Member of the Technical Committee on Factory Automation of the Industrial Electronics Society (IES). Co-chair of the Subcommittee 10 “Intelligent Sensors and Sensor Networks in Industrial & Factory Automation”.

Team Leader	
	Dr. Pau Martí Technical University of Catalonia, Barcelona, Spain URL: http://www.upcnet.es/~pmc16/
Technical role(s) within Artist2	Real-time systems and control systems co-design
Research interests	Real-time and control systems, overload handling, jitter analsyis 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.

Team Leader	
	Prof. Ivo De Lotto Robotic Lab, University of Pavia, Italy http://www.unipv.it/ingegneria/servizi/scheda.php?mat=000300
Technical role(s) within Artist2	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.

Awards / Decorations	Gold Medal of Italian Ministry of Education (1988)

Team Leader	
	Prof. Marisol García-Valls Universidad Carlos III de Madrid URL: http://www.it.uc3m.es/mvalls
Technical role(s) within Artist2	UC3M leader on Adaptive resource management for CE”
Research interests	Distributed embedded systems, design and modelling of real-time systems, real-time programming languages, quality of service
Role in leading conferences/journals/etc in the area	Member of the Programme Committee of conferences such as ARCS 06, EstiMedia 04-06, JTRES 03-04, EUC 05, EMSOFT 03-04 Reviewer of the Real-Time Systems Journal
Notable past projects	ARTIST: Advanced Real-Time Systems. URL: http://www.artist-embedded.org MUSE: MUlti Service Access Everywhere Everyware: Personalized services in ubiquitous environments

Team Leader	
	Prof. Julian Proenza University of the Balearic Islands URL: http://dmi.uib.es/research/SRV/jpa_ppl_en.htm
Technical role(s) within Artist2	Team leader of affiliated partner. Indirect participation in ART Cluster, with the core team University of Aveiro
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 in the area	Chair of several workshops in his fields of interest. Participation in several Organizing and Program Committees of related events.

4.4 Affiliated International Partners

	Professor Tarek Abdelzaher, University of Illinois at Urbana-Champaign http://www.cs.uiuc.edu/homes/zaher/
Technical role(s) within Artist2	Technical expert
Research interests (optional)	Operating systems, networking, sensor networks, distributed systems, and embedded real-time systems.

	Professor Lui Sha, University of Illinois at Urbana-Champaign http://www.cs.uiuc.edu/directory/directory.php?name=sha
Technical role(s) within Artist2	Technical expert.
Research interests	Distributed real-time computing systems, dynamic real-time architecture, QoS driven resource management and security and fault tolerance in networked embedded systems.

	Professor Sanjoy Baruah, University of North Carolina at Chapel Hill http://www.cs.unc.edu/~baruah/
Technical role(s) within Artist2	Technical expert.
Research interests	Schedulability analysis and multiprocessor systems.

5. Internal Reviewers for this Deliverable

Karl-Erik Arzen (Univ. of Lund, Sweden)

Marco Caccamo (University of Illinois at Urbana Champaign, USA)