Policy Objective (abstract)
An embedded hardware-software system is adaptive, if it can modify its behavior and/or architecture to changing conditions and requirements. Adaptivity is increasingly important as the complexity and autonomy of embedded systems increases. Adaptivity is a cross-cutting system characteristic that affects hardware and software as well as modeling, architecture, and run-time support. This deliverable summarizes the achievements of the activity during Y4 of ArtistDesign.
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1. Overview

1.1 High-Level Objectives

An embedded hardware-software system is adaptive, if it can modify its behavior and/or architecture to changing requirements. Adaptivity is increasingly important as the complexity and autonomy of embedded systems increases. Adaptivity is required both off-line at design-time and on-line at run-time. Design-time adaptivity is required in order to be responsive to changes in system specifications and to support platform-based or product-family based development. On-line adaptivity is required to be able to dynamically respond to changing conditions and contexts and through this improve performance and resource utilization. The changes can involve different types of resource requirements, changing system objectives, and changing external conditions.

Adaptivity is a cross-cutting system characteristic that affects both hardware and software. At the software-level adaptivity is mainly concerned with flexible and adaptive resource scheduling, e.g., CPU time scheduling. At the hardware-level adaptivity includes both adaptation of operation modes, e.g., supply voltage and clock frequency, processor instruction sets, and dynamic management of hardware resources, e.g., processing elements and memory.

The cross-cutting nature of adaptivity implies that it affects all aspects of embedded system design. The high-level objective of this thematic activity is therefore to integrate the efforts and combine the competences related to adaptivity in embedded systems within the four thematic clusters. The main way of achieving this is to create suitable interfaces, meeting points, and research contacts between the partners. Another important objective for this activity is to define the ontology for adaptivity in embedded systems, i.e., the relationship between adaptivity, reconfigurability, flexibility, sustainability, and robustness, and the relationship between adaptivity and predictability.

Although partners from all the four thematic clusters are part of this activity, it is partners from the Operating Systems and Network cluster that dominate. Hence, the majority of the partners are working on issues related to adaptive resource management, including CPU scheduling and QoS management; adaptive networking, and operating and middleware support for adaptivity. The use of feedback and control-theoretical approaches in order to achieve adaptivity is also studied by several partners. However, the activity also contains partners with interests in modeling of adaptive processes and applications, hardware (run-time) reconfigurability, and timing analysis support for adaptability.

The joint research within the cluster can be divided into three areas:

- **Adaptive resource scheduling**
  This area concerns adaptive scheduling in which schedules and task parameters are dynamically modified in order to prevent overload conditions and minimize some application-related cost function, e.g., control performance or energy consumption. The area includes mechanisms for achieving adaptivity both on a task level and on a system level, adaptive resource reservations, QoS management, and control-based mechanisms for achieving adaptivity. The area applies to a wide range of resource types, although the majority of the work will be focused on CPU and communication bandwidth

- **Hardware-based adaptivity**
  This area concerns dynamic management of hardware resources (processing
elements, memory, communication interconnect) to meet dynamic resource requests from the software and to cater for different application domains both at design time and run time. It contains mechanisms for adaptation of hardware modes of operation.

Hardware-based adaptivity also includes modeling of adaptive processes and applications and hardware generation for such systems.

- **Adaptive networking**
  
  This area includes different mechanisms for supporting adaptivity in communication networks, excluding on-chip networks. It includes dynamic ad hoc routing mechanisms in sensor network applications, adaptivity in network protocols at various levels to cater for dynamically changing application demands, and application-aware networking.

-- Changes wrt Y3 deliverable --

*No changes with respect to Year 3.*

### 1.2 Industrial Sectors

The use of adaptive resource management is of particular interest for soft real-time applications, e.g., multimedia applications within consumer electronics systems and in telecommunications. Consumer electronics 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. 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. As a consequence, these systems are prone to intermittent overload conditions that could degrade the performance in an unpredictable fashion.

The introduction of multicore platforms also in embedded applications creates new design challenges. A particular problem compared to uniprocessor platforms is the WCET analysis. Due to the shared memory access WCET analysis runs the risk of being very conservative. This will most likely hamper the application of hard real-time techniques based on static analysis. Hence, the market for more dynamic or adaptive resource management based on feedback from the true resource utilization and/or the application quality-of-service can be expected to increase in the future.

Another challenge, not only for embedded systems, but for all computing systems is the increased variability in circuit delays and power consumption caused by quantum effects in sub-45 nm chips. This causes classical device estimation models to fail and creates a need for variability-aware designs in which monitors and “variability knobs” can be used to dynamically adjust operating points.

Also in industrial sectors where predictability is the main concern there is always a certain need for adaptivity. For example, companies like Boeing have expressed a need for active resource management and dynamic scheduling as well as to handle, during system execution, things that were not anticipated at design-time. The automotive industry also has expressed increasing needs to handle software upgrades in a robust way and flexible attachment of devices (e.g. PDA’s, especially in the infotainment domain). In addition to resource management, this requires more stringent configuration management (be it on-line or support by off-line tools) that ensure that new configurations are compatible (both in a functional and non-functional sense).
A current trend is to use the word *autonomy* rather than *adaptivity* to describe these types of systems. Although the basic meaning is the same the word autonomous typically reflects an even higher degree of automation than what the word adaptivity does. For example, an embedded system that at run-time is able to switch between a limited number of pre-defined, and possibly pre-verified, configurations would typically be considered as adaptive but hardly as autonomous.

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

*Minor changes with respect to Year 3.*

### 1.3 Main Research Trends

Real-time systems constitute a notable share of today’s embedded computers that needs special attention. The design of robust and fault-tolerant real-time systems is a highly active research area that has produced numerous approaches for evaluating and increasing system robustness against selected fault scenarios. These methodologies can be applied throughout the design process of an embedded system and yield systems that are highly robust against a selected set of disturbances in the field. Future embedded systems, however, will undergo an evolution in both hard- and software configuration during their lifetime. In the automotive industry, it is already common to update or add software components during the lifetime of a product, producing a variety of software configurations in the field. To ensure functional and temporal correctness of all possible configurations, OEMs have to maintain a complex versioning database and perform exhaustive testing to cover the whole configuration landscape. This already constitutes a problem today, which will grow into a major challenge in the future.

Designing embedded systems to be robust and fault-tolerant will not ultimately solve this problem, as the evolution an embedded system goes through during its lifetime cannot be foreseen at design time. Hence, embedded systems need to be adaptive to changing conditions, in the sense that they need to be able to meet given requirements including safety, security, and performance, in the presence of uncertainty in its external environment or internal execution platform. Adaptivity can be seen as a means for enforcing predictability in the presence of uncertainty.

The uncertainty can be viewed as the difference between the average and the worst-case behavior of a system and its environment. The trend in embedded system is towards drastically increasing uncertainty due to, e.g., execution platforms with increasingly sophisticated HW/SW architectures (layering, caches, multiple cores, speculative execution etc), increased connectivity with complex and non-deterministic external environments, increased amount of difficult-to analyze software, and increased variability with respect to use cases.

One technique for achieving adaptivity in particular in software-based systems is feedback. In many embedded systems worst-case designs are unfeasible for several reasons. One of these is the over-provisioning of resources that this typically implies. Other reasons are uncertainties associated with worst-case resource utilization estimates and on-line changes in objectives, external conditions and use cases. In a feedback-based resource management system, the allocation of resources is based on a comparison of the actual resource utilization by, e.g., a set of activities or tasks, with the desired resource utilization. The difference is then used for deciding how the resources should be allocated to the different activities. The decision mechanism constitutes the feedback controller in the scheduling scheme. Feedback control makes it possible to deal with uncertainties and variations in a controlled way.
Feedback scheduling is primarily suited for soft real-time applications and adaptive real-time applications, where missing one or more deadlines does not jeopardize correct system behavior, but only causes performance degradation. For this type of systems, the goal is typically to meet some Quality of Service requirement. The adaptive class of real-time systems is a suitable description for many practical applications. This includes different types of multimedia applications, but also many control and signal processing applications. An important research trend here is how to best model embedded computing system from a control perspective. Different model formalisms can be considered, from pure discrete event based models to fluid continuous-time approximative models.

The research trends related to adaptivity in embedded systems are numerous since adaptivity is crosscutting. In hardware-based oriented embedded systems there are work performed on modeling and hardware generation for adaptive processes and applications. Emerging architectures such as partially reconfigurable, either fine-grained or coarse-grained, FPGAs provide a huge potential for adaptivity in the area of embedded systems. Since many system functions are only executed at particular points of time they can share an adaptive component with other system functions, which can significantly reduce the design costs. However, adaptivity adds another dimension of complexity into system design since the system behavior changes during the course of adaptation. This imposes additional requirements on the design process, in particular system verification.

In the software-oriented part of embedded systems there is also a considerable work on computational models that allow for adaptivity, how adaptivity can be provided in component-based architectures, adaptive task models for scheduling, program language constructs supporting adaptivity, and run-time support for adaptive resource management from operating systems, middleware, and communication networks. The resources in the latter case typically include clock cycles, memory, communication bandwidth, and energy, but could in general also include other resources which are allocated dynamically.

The cyber-physical system (CPS) trend has also strong relations to the work within this activity. One example of this is holistic design approaches that integrate physical aspects such as power and heat, with cyber aspects.

-- Changes wrt Y3 deliverable --

Minor changes with respect to Year 3.
2. State of the Integration in Europe

2.1 Brief State of the Art

Since adaptivity affects all layers of system development and all the thematic areas in ArtistDesign it is quite difficult to provide a brief technical state of the art description. Here, we have focused on the industrial state of the art. For a description of the state of the art in research we refer to the respective thematic cluster reports.

Adaptive resource management is primarily of interest in consumer electronics, industrial automation, and telecommunications. Mobile cellular terminals today are getting more and more advanced and their source code consists of 5-15 million lines of, typically C, code involving a large number of parallel activities. For these applications, the use of adaptive resource management would allow to safely mix real-time and non real-time processes. The majority of the activities are related to multimedia streaming, where multiple video and audio streams are common. It is not uncommon to have a desired system utilization that is well beyond 100 %. Designing the system for the worst-case scenario is not economically justified. Hence, adaptivity is needed in order to be able to dynamically tradeoff the quality of the activities.

In telecommunication companies, the main current interest seems to be in exploring the use of the Linux OS and its real-time extensions. QoS mechanisms, virtualization and reservation-based scheduling, multi- and many-core platforms, and data-flow based programming models are also attracting substantial interest.

In the area of Industrial Automation, the continuous increment in processing power and memory capacity in local processors gives the opportunity to add new tasks into them, increasing system complexity in terms of supervision, diagnostics, presentation, communication, etc. Adaptive task scheduling that preserves the real-time constraints is a possible way to handle such situations and manage the complexity of the application.

Reconfigurable hardware systems are a technique that for a long time has not been able to compete either with software-based systems or with ASIC-based solutions. However, there are signs that that is about to change, especially for applications where the gains in performance over software-based system and the faster development cycle compared to ASICs are important.

The multi/many-core trend also narrows the gap between software and hardware-based implementation techniques. In both cases good models are needed for exploiting parallelism, both in the programming models and languages used and in the compilers and analysis tools. Ideally, it should be possible to execute the same application either on a FPGA with a high-level of parallelism or on a, e.g., quad-core, platform without having to change anything in the source.

--- Changes wrt Y3 deliverable ---

No changes with respect to Year 3.
2.2 Main Aims for Integration and Building Excellence through ArtistDesign

Adaptivity is a concern which cuts vertically across all levels of abstraction in embedded systems design, spanning from high-level requirements to implementation details on specific platforms. It therefore needs to be carried out in a synergistic manner, and is therefore the subject of a transversal activity involving all clusters of the NoE. In Artist2 adaptivity-related issues were spread out among different activities in different clusters. The main purpose of this activity is to integrate research teams working on different aspects of adaptivity in embedded systems design.

-- Changes wrt Y3 deliverable --

No changes with respect to Year 3.

2.3 Other Research Teams

The main teams in Europe on software-related adaptivity in embedded systems are part of ArtistDesign and this activity. In the more hardware-related area some of the leading teams in Europe belong to ArtistDesign but not all. The ones that are outside ArtistDesign mostly are part of the HiPEAC NoE (http://www.hipeac.net/members_new) which has separate clusters on reconfigurable computing, adaptive compilation and multi-core architectures. However, several of the ArtistDesign partners also belong to HiPEAC, e.g., IMEC, CEA, Aachen, TU Braunschweig, UDortmund, and UBologna. Hardware-based adaptivity is also the focus of the ANDRES project (http://andres.offis.de/) in which OFFIS, TU Vienna, KTH, UCantabria and Thales participate. The same situation holds for the sensor network field. Several very strong European groups are not part of ArtistDesign, e.g., TU Berlin and SICS. The sensor network and cooperating object NoE in FP7 that runs in parallel with ArtistDesign is CONET (http://www.cooperating-objects.eu/). Organic computing systems which adapts dynamically to the current conditions of its environment through self-organization, self-configuration, self-optimization etc is the topic of the priority program 1183 funded by the German Science Foundation (DFG) (www.organic-computing.de/spp). Here several German teams participate.

Within US there is large amount of research on different aspects of adaptivity in embedded systems and on the use of control in embedded systems. Most of the software-based parts of this currently go under the label cyber-physical systems, an area where NSF has large programmes. Strong research groups in the US include UIUC (Abdelzaher, Sha), Virginia (Son, Stankovic), CMU (Rajkumar), UNC (Baruah, Anderson). There are also interest in related topics from several control groups in the US, e.g., Berkeley (Sastry), UIUC (Dullerud, Basar), Caltech (Murray, Doyle), CMU (Krogh) just to name a few.

-- Changes wrt Y3 deliverable --

Minor changes with respect to Year 3.
2.4 Interaction and Building Excellence between Partners

The interaction and work within this activity consist of individual and joint research projects (see Chapter 3), jointly organized meetings and workshops (see Chapter 3 and 5), and jointly organized educational events (Chapter 3).

--- Changes wrt Y3 deliverable ---

*The same as Y3.*

*The actual interactions and excellence building are described in Sections 3 and 5.*

2.5 Interaction of the Transversal Activity with Other Communities

The partners of the activity interact with several other research communities. These include the high-performance computing community, the sensor network community, and the control community at large and in particular the networked control community. The partners also interact with different industry branches, e.g., the automotive industry, e.g., through the network created by the DySCAS project, the microelectronics industry (through interactions with STMicroelectronics and NXP), the telecom industry (through Ericsson). The partners also have strong links to several US groups, e.g. UIUC, UNC and UVA, with Tarek Abdelzaher, Lui Sha and Sanjoy Baruah as affiliated international partners to ArtistDesign.

The partners also interact with the partners of the European projects that they participate in which do not belong to ArtistDesign. These projects include ACTORS, HiPEAC, PREDATOR, COMBEST, MOSART, ANDRES, REALITY, CHAT, FlexWARE, GUARANTEE, RT-Model, CHESS, MOSART, Touchmore, and T-CREST.

--- Changes wrt Y3 deliverable ---

*No changes with respect to Year 3*
3. Summary of Activity Progress

The following summarizes the technical activities that are part of this activity. Certain parts have been omitted due to the fact that they already are reported in the deliverables from the thematic clusters. It has been our attempt to reduce any overlap to the minimum. However, since all deliverables are generated in parallel it is still possible that there is a certain overlap.

It should be emphasized that in the majority of the cases the actual research work described below has only marginally been funded by ArtistDesign. In most cases the funding comes from other national or European projects. The role of ArtistDesign is to provide the networking “glue” between these activities.

3.1 Technical Achievements

Here the technical achievements of the partners, both jointly and individually, during Year 4 are summarized. Although the distinction is often difficult an attempt has been made to structure the achievements in three groups: adaptive resource scheduling, adaptive networking, and hardware adaptation. In the first and largest group we also include work on modelling and analysis relevant to adaptation.

3.1.1 Adaptive Resource Scheduling

Adaptive and feedback-based resource management (SSSA, ULUND, TUKL, Evidence, Ericsson)

Several of the partners from the OS and Networks cluster have worked together in the STREP project ACTORS coordinated by Ericsson which ended in February 2011. ACTORS addressed design of resource-constrained software-intensive embedded systems with high requirements on adaptivity and efficiency. Three techniques were combined: virtualization, feedback control, and data-flow programming models. In ACTORS applications were expressed in the CAL actor based data-flow language. During the final review meeting the three demonstrators developed in the project, a control demonstrator, a wireless media demonstrator, and an image processing demonstrator, were presented. During the rest of the year ULUND and TUKL have continued the development of the adaptive resource manager, partly using ArtistDesign funding. This work will also continue during the coming years, partly funded by a Swedish VR grant 2012-2015.

Web site: [http://www.actors-project.eu/](http://www.actors-project.eu/)

Feedback control of computing systems (ULUND, UIUC, Ericsson)

The work performed by ULUND and Ericsson on feedback control of web servers reported in Y2 and Y3 continues. This year the work has led to two publications. Prof Tarek Abdelzaher from UIUC who has been on a sabbatical at ULUND has participated in this work.

Theory of Distributed Performance Analysis (TU Braunschweig)

In Y4 TU Braunschweig has continued the research on bounding the execution time of system-level analysis. They have developed a formal modeling of the distributed analysis. With this modeling they were able to formally prove the convergence of the iterative algorithm and the
equivalence to the original offline tool. Furthermore, the modeling yielded a correctness proof of the algorithm. The results are currently under submission.

In-System Sensitivity Analysis for Real-Time Systems (TU Braunschweig)

In Y4 the methodology developed in the previous years for in-system sensitivity analysis has been further improved to provide more accurate bounds. The results are currently under submission.


TU Braunschweig has continued developing the EPOC platform which allows safe updates in hard real-time systems. In particular they have focused on configuration, monitoring and isolation of software components according to the corresponding verification model. This allows enforcing the parameters that are verified within the in-system admission control.

Analysis of Mode-Changes in Real-Time Systems (TU Braunschweig)

TU Braunschweig has analyzed the effects on system timing when a switch between two configurations/modes is performed in a real-time system. Bounding these effects is necessary to account for the transient influence that occurs whenever changing a system configuration, e.g. through updating software. Specifically they have developed an analysis to determine the maximum duration of these transient effects.

Parametric WCET analysis (MDH)

The work on parametric WCET analysis, initiated with USaar, has continued in 2011. An improved value analysis, based on a bit-precise relational domain, has been developed. This value analysis handles arithmetic wraparounds correctly, and can be used to calculate sound parametric loop bounds also for codes with wraparounds. The analysis has been implemented in the WCET analysis prototype tool SWEET. For details, see the Timing Analysis activity report.

Mode Transitions with mode Independent Tasks in Multicore Systems (IPPorto)

Embedded real-time systems often have to support the embedding system in very different and changing application scenarios. The different application scenarios are reflected in the software structure with a changing task set and thus different operational modes. At the same time there is a strong push for integrating previously isolated functionalities in single-chip multicore processors. On such multicores the behavior of the system during a mode change, when the systems transitions from one mode to another, is complex but crucial to get right. Examples are in the automotive domain, where in the future different applications may share a multicore platform. In this context it is crucial to bound the time to start an application of some criticality, while ensuring that other applications already processing are not unduly affected. Careful orchestration of the mode change is critical to ensure no timing anomalies occur.

Among other things IPPorto has developed an analysis which considers mode changes in multicore systems, which use global EDF to schedule a set of mode independent (MI) and mode specific (MS) tasks. In such systems, only the set of MS tasks has to be replaced during mode changes, without jeopardizing the schedulability of the MI tasks. Of prime concern is that the mode change is safe and efficient: i.e. the mode change needs to be performed in a predefined time window and no deadlines may be missed as a function of the mode change.
IIPorto has also investigated the impact of mode changes in multicore systems which are partitioned scheduled. What distinguishes this problem from a unicore approach is that during the transition a migration of a mode independent task may be required.

http://www.cister.isep.ipp.pt/docs/global%252Dedf+scheduling+of+multimode+real-time+systems+considering+mode+independent+tasks/629/

http://www.cister.isep.ipp.pt/docs/partitioned+scheduling+of+multimode+systems+on+multiprocessor+platforms:A+when+to+do+the+mode+transition+/627/

Comparing schedulers and energy management strategies (IPPorto)
The academic community in the area of real-time systems is in need to compare the posed scheduling and energy/power management approaches. In order to serve this need IPPorto has developed the SPARTS, a simulator of a generic embedded real-time device. The tasks in the simulator are described by externally visible parameters (e.g. minimum inter-arrival, sporadicity, WCET, BCET, etc.), rather than the code of the tasks. It is designed to be extensible to accommodate different task properties, scheduling algorithms and/or hardware models for the application in wide variety of simulations. Of particular concern is the modularity of the hardware modelling, in which IIPorto has modelled Unicore, Multicore and MPSoC systems. The interfaces are designed such that the simulator or parts thereof can easily be connected to other analysis tools developed in the community. The source code of the SPARTS is available for download at IPPorto website.

Weblinks:
http://www.cister.isep.ipp.pt/projects/sparts/
http://www.cister.isep.ipp.pt/docs/sparts:A+simulator+for+power+aware+and+real-time+systems/666/

Code offloading in adaptive real-time distributed systems (IPPorto)
Highly dynamic distributed systems with Quality of Service (QoS) constraints (most importantly real-time constraints) can benefit from code offloading techniques, so that parts of the application can be offloaded and executed, as services, by neighbour nodes, which are willing to cooperate in such computations. A typical use case would be on mobile devices, where code off-loading to infrastructure nodes can be used to minimise energy consumption of a mobile device. Alternatively off-loading may be exploited to opportunistically obtain increased service quality for applications.

To that purpose a code offloading framework has been built, integrating support to code mobility, which is responsible for the transfer of code and state between cooperating nodes and execution control. This framework is built on top of CooperatES, an existing QoS framework developed by IPPorto, which allows finding a proper coalition of nodes to run a distributed application, based on the resource requirements (CPU, memory, display, etc.) of the services constituting the application.

The main objective of the offloading algorithm is to dynamically adapt to the varying execution times by offloading computations to surrogate nodes in a timely fashion. By timely it is meant that the user should not notice any disruption on the application’s behaviour, due to code mobility, meaning that local or remote execution (including communications) should be completed within the application deadlines.

Weblinks:
Dynamic behavior of embedded systems (IMEC)

In this context Imec has developed run-time task assignment strategies for multiple video decoding on heterogeneous architectures where task priorities are defined based on the impact of the task scheduling on the end video quality.

Additionally, the work on load balancing at device level has been extended to load balancing at network level, where processing resources are shared among devices in the network. In this respect, a strategy based on genetic algorithms has been developed to assign video processing tasks onto heterogeneous architectures in the grid while optimizing multiple and conflicting objectives. Specifically we maximize task execution quality while minimizing energy and bandwidth consumption in the grid. Moreover, in our video processing scenario transcoding to lower spatial/temporal resolutions is considered in order to tradeoff between video quality and processing and bandwidth demands.

In collaboration with BARCO, an implementation of a resource manager for video processing clusters has been evaluated. This case-study showed that a run-time managed solution improved energy efficiency, reduced hardware cost and reduced form factor, without sacrificing the quality of service. In order to facilitate the integration of the resource manager in other systems, the resource manager was ported to an OSGi-based component middleware platform under development by KULeuven.

Adaptive control of MPEG-4 decoding (TUKL, ULUND)

Decoding MPEG-4 streams in resource constrained system faces the challenges of matching varying resource demand (due to MPEG-4 encoding) to varying resource availability (due to varying network bandwidth or CPU availability). Adaptation has to meet the demand of high resource utilization and avoiding issues such as oscillation between over and under utilization of resources, which can bring the system to an unstable state with low resource utilization.

Adaptation methods for MPEG-4 have been developed and included in the ACTORS resource management framework demo. The control related aspects have been discussed further, notably at the LCCC workshop in Lund, which brought together a range of researchers from computing and control.

Improving real-time BIP (Verimag).

The work on using the BIP component model for model-based design using the notion of logical execution time described in the Y3 deliverable has continued. The implementation consists of RT-BIP, an extension of the BIP language for modeling real-time systems, and a Real-Time Engine used for their execution. They consider that the application software is a set of interacting components. Thus the abstract model corresponding to the application is the parallel composition of the timed automata representing the components. The Real-Time Engine executes sequences of interactions of the components by taking into account their timing constraints, depending on the actual time provided by the real-time clock of the platform.
The approach has been tested in two case studies. The first is a module of a robotics application. They showed the benefits from using RT-BIP, in terms of CPU utilization and simplification of the corresponding model, compared to an implementation using BIP where time progresses by synchronous execution of ticks. They also studied time-safety and time-robustness for a non-trivial multimedia application - an adaptive MPEG video encoder modeled in BIP. They finally showed that the application is not time-robust and explained how its time-robustness can be enforced using two different methods.

Modelling of extra-functional properties (UPM)

Model driven development is a powerful mean for off-line adaptivity. The use of model transformations, including code generation allows for adapting final code to changing software and hardware requirements. UPM is working at developing support for including extra-functional annotations on pure functional models. Considered properties are safety, security, and time. These annotations are used in model transformators for generating input data for analysis tools, intermediate models, and code generation. Changes in any of the types of requirements on platform independent models are automatically reflected in the generated models, without programmer intervention. For example, the priority of the generated threads may change if time requirements are changed or if a different execution platform is selected.

Adaptation in service-oriented architectures (UPM)

Service Oriented Architectures (SOA) provides a number of advantages for current applications, such as making it easier applications deployment and service discovery. In this type of applications, it is common the co-existence of applications with and without safety and time requirements. UPM is working towards techniques for adapting the service request handling behaviour to the specific requirements of the services. The approach taken is to use CPU contracts to ensure some computation time for dealing with services with special requirements. There is a running implementation of modules for providing this functionality on the Linux kernel. This has been used in the context of the project RT-Model. In addition, the basic principles of this approach have been used in the project GUARANTEE for handling events with safety requirements.

Adaptive Temperature Management (ETH Zurich)

In the last year, substantial progress has been made in the area of adaptive thermal management. Dynamic thermal management (DTM) techniques to manage the load on a system to avoid thermal hazards are soon becoming mainstream in today’s systems. With the increasing percentage of leakage power, switching off the processors is becoming a viable alternative technique to speed scaling. For real-time applications, it is crucial that under such techniques the system still meets the performance constraints. ETH studied stop-go scheduling to minimize peak temperature when scheduling an application, modeled as a task-graph, within a given makespan constraint. Moreover, ETH proposed a novel approach to this problem with the use of shapers to adaptively and selectively insert idle times during the execution of hard real-time jobs on a single speed processor. For the class of leaky bucket shapers which have a lightweight implementation, it has been derived the shaper such that no job misses its real-time deadline and the peak temperature is optimally reduced. The analysis and design of such shapers allows for dynamically variable streams of jobs; for instance, periodic streams with jitter.

Adaptive Timing Management (ETH Zurich, UIUC)
Modern multiprocessor and multicore architectures adopt shared resources to meet increased performance requirements. Adaptive arbiters, such as FlexRay, have been adopted to grant access to shared resources. While increasing the performance, timing analysis is more challenging with this kind of arbiter. It has been considered real-time tasks that are composed of superblocks, while superblocks themselves are composed of phases. Based on dynamic programming, an algorithm that safely derives an upper-bound of the worst-case response time of a phase has been developed. The worst-case response time of a task can then be determined for either sequential or time-triggered execution of superblocks. This work is joined work with Marco Caccamo, Univ. Illinois.

Adaptive Power Management (ETH Zurich, SSSA)

Energy consumption has become an important issue for modern embedded systems. This is because, one does not only like to deploy high-performance systems and provide guaranteed services, but also request system deployments to last as long as possible. With online dynamic power management (DPM), one adaptively changes the system’s power mode, i.e., schedules when to turn on and off on-the-fly, to achieve energy savings. The work explores how to apply dynamic power management to reduce static power for hard real-time systems. They propose online algorithms that adaptively control the power mode of a system, procrastinating the processing of arrived events as late as possible. To cope with multiple event streams with different characteristics, they provide solutions for preemptive earliest-deadline-first and fixed-priority scheduling policies. By adopting a worst-case interval-based abstraction, the approach can not only tackle arbitrary event arrivals, e.g., with burstiness, but also guarantee hard real-time requirements with respect to both timing and backlog constraints.

Sampling mechanisms for event-driven control systems (UPC, SSSA)

The work performed on sampling mechanisms for event-driven control systems reported in Y3 continues. This year the work has focused on developing a sampling mechanism for event-driven controllers that allows determining at each job execution when the next job execution should occur in order to minimize control cost (expressed in terms of a finite-horizon continuous-time quadratic cost function) while minimizing controllers’ computational demand (i.e., the number of generated control updates). The novelty of this approach is that the event-condition that triggers control updates considers both control performance and resource utilization.

Optimal online sampling period assignment (ULUND, UPC)

The work performed on sampling mechanisms on optimal online sampling period assignment reported in Y3 continues. The work has led to one publication.

Variability aware allocation and scheduling (UNIBO, STM)

Multimedia streaming applications running on next-generation parallel multiprocessor arrays in sub-45nm technology face new challenges related to device and process variability, leading to performance and power variations across the cores. In this context, Quality of Service (QoS), as well as energy efficiency, could be severely impacted by variability.

UNIBO and STM have closely collaborated to tackle this issue. UNIBO and STM research proposes a run-time variability-aware workload distribution technique for enhancing real-time predictability and energy efficiency based on an innovative Linear-Programming + Bin-Packing
formulation which can be solved in linear time. This approach has been demonstrated on a virtual prototype of a next-generation industrial multi-core platform running representative multimedia applications.

Experimental results confirm that this technique compensates variability, while improving energy-efficiency and minimizing deadline violations in presence of performance and power variations across the cores. The proposed policy can save up to 33% of energy with respect to the state-of-the-art policies and 65% of energy with respect to one variability-un-aware task allocation policy while providing better QoS.

**Mode management and architecture for automotive embedded systems (KTH)**

Initiated by Denso, a new collaboration was started as a smaller research project during 2011 between KTH, Denso and TUM. The problem setting is provided by the evolution of automotive embedded systems, driven for example by new electrical auxiliary subsystems, electrical and hybrid propulsion, energy management, and active safety systems. All these new functionalities will share sensor, computer and actuation resources and have multiple modes of operation which imply different resource usages in each mode of operation. Managing, designing and verifying such multimode systems is seen as a key challenge.

Unless proper design methods are made available, unintended feature interaction is likely to occur with potentially catastrophic consequences. Moreover, the cost of for example assessment of impact of changes and system verification will be growing significantly. Methods to support design will pave way for efficient analysis and optimization.

In order to address these challenges Denso initiated a prestudy project, in which, based on a pre-competition, KTH and TUM were selected to participate. In the ongoing project the goal is to develop a mode taxonomy, to propose means for modeling of functions and resources that support analysis of resource sharing, to provide architectural guidelines and proposals and to carry out an industrial case study. During 2011, initial studies were performed and several meetings took place including a physical workshop hosted by Denso in Munich.

### 3.1.2 Adaptive Networking

**Online adaptation of QoS in video transmission over Ethernet (UPorto, Aveiro, Valencia)**

The transmission of video can be subject to strict time constraints, e.g., in interactive multimedia applications and machine vision. Such cases might impose the use of low latency codecs such as MJPEG that do not explore temporal redundancy. In these cases the resulting video frames are variable in size and depend on the details of the current image. Our work allowed transmitting several video streams in different virtual channels with guaranteed bandwidth and latency while making an efficient use of the channel bandwidth by adapting the compression factor online to keep the frames within a desired range. Moreover, when the compression was too high, the bandwidth of the channels was adapted online to give more to those using higher compression at the expense of those that were using less compression. This scheme allowed increasing the number of transmitted video streams within the same total bandwidth.

Another study was the impact of different bandwidth allocation strategies in the QoS of the video transmission process, either favouring the adaptation of the frame rate or the frame size. A significant impact was observed, but being highly dependent on the video contents. Further work will research the possibility of also adapting such strategy online to the current video sequence.
Dynamic adaptation of virtual channels within hierarchical frameworks (Aveiro, UPorto, Malardalen)

The provision of virtual channels with guaranteed bandwidth and latency in networks such as Ethernet is becoming more appealing to cater for distributed real-time applications and high integration levels with temporal isolation. This target was achieved with an enhanced Ethernet switch developed at Aveiro and University of Porto, within which a hierarchical scheduling framework was setup. This was generally reported in the resource management deliverable and is referred here concerning the specific feature of online adaptation at different levels of the channels hierarchy, for the sake of completeness. This hierarchical dynamic adaptation was demoed with a working prototype using a video surveillance application.

QoS adaptation in service-oriented architectures (UPorto)

The service-oriented paradigm brings a high potential for code reusability and quick composition of applications, including in real-time systems. In these systems it is likely that several services will be implemented in different ways, with different implementations exhibiting different levels of QoS. The iLAND ARTEMIS project aims at defining an architecture to support the QoS-oriented dynamic recomposition of services, using the most adequate service implementations, in bounded time. The team at UnivPorto developed a laboratory prototype around a simple video monitoring application, which exhibits time-bounded service recomposition to maximize QoS adapting to the resources available. This prototype was demoed at RTSS.

Adaptation of the beacon rate in tracking cluster-based wireless sensor networks (UPorto, Zhejiang University)

One common application of wireless sensor networks is tracking of objects within certain areas. Improving tracking accuracy, however, requires faster sampling rates but this conflicts with low duty cycle operation for long longevity. Therefore, this work researched the possibility of generally using a long beacon period for low energy operation while no target is being tracked, and changing to a short beacon period whenever a target is detected. A particular mechanism allows increasing the beacon rate in the clusters that are directly involved in the tracking action while the other clusters remain operating with low beacon rates, despite being all synchronized. An experimental characterization of this mechanism confirmed the potential for high energy savings while preserving good tracking accuracy when compared to fixed beacon rate approaches.

Fault Tolerant and Reliable Communication Platforms (KTH)

KTH is developing a fault tolerant on-chip communication platform covering the link level, network level and end-to-end level. In the course of further technology scaling, the complete avoidance of faults will be more and more expensive. It is expected that both wear-out permanent, intermittent, and transient faults will occur more frequently in future technology generations, and architecture-level techniques have to be deployed to tolerate them. To address these concerns, KTH is developing adaptive routing schemes that allow for fault tolerance in various architectures, topologies and under a range of fault models and assumptions.

In the previous year KTH has developed two routing algorithms for mesh topologies with very different trade-offs regarding cost, performance, and the level of fault tolerance. Fault-on-neighbor (FoN) is cost effective scheme with small overhead that tolerates a range of fault
patterns in the network, but fails under certain fault scenarios. Q-learning based reconfigurable routing (FTDR) is a more expensive and more general routing scheme that can cope with all kinds of fault patterns. A hierarchical variant (FTDR-H) has been demonstrated with good scalability properties and moderate growth of cost as the network scales.

Both FoN and FTDR are based on deflective routing, which is a highly adaptive routing algorithm and lends itself naturally to fault tolerance. This year they have explored the features of deflective routing more systematically with respect to cost, performance and fault tolerance and have extended it to a range of other topologies beyond 2-dimensional meshes. They have studied deflective routing variants for torus, Manhattten Street Network (MSN), Spidergon, and DeBruijn graph topologies. Specifically they have noted that certain DeBruijn graphs match deflective routing particularly well with better performance at comparable or lower cost than all other studied topologies. E.g. DB(2,4) DeBruijn graphs have the same or better performance as torus topologies at 1/3 of the area cost under a range of application traffic scenarios.

They have also extended their fault tolerant routing strategy to 3-D topologies when silicon dies are stacked upon each other and connected with high bandwidth, low latency Through Silicon Vias (TSV). A study has shown that a deflective routing scheme based on limited, so called layered routing tables, can tolerate 10% of damaged links at 5% performance loss at reasonable cost and with comparably low power consumption.

3.1.3 Hardware-Based Adaptivity

eDNA: Reconfigurable self-organising and self-healing hardware platform (DTU)

The focus in 2011 has been on three main areas:
- Implementation of fault detection in eDNA prototype
- Finishing PhD thesis related to the eDNA project
- Preparing eDNA for spin-off company

Part 1 was completed successfully in the spring of 2011 and resulted in a paper which was submitted and presented at the NASA/ESA Conference on Adaptive Hardware Systems 2011 in San Diego. A paper dealing with optimizing of the placement of spare cells on the eDNA architecture was also presented at the same conference. They have also submitted a journal paper for the Transactions on Aerospace and Electronic Systems, which describe the whole eDNA project. A PhD thesis was completed May 31st about the eDNA architecture. The group is currently trying to commercialize the technology through a spin-off company. During the last 6 months they have successfully identified a highly scalable market in cooperation with a Danish partner with whom they are currently targeting a launch of an eDNA based product within a 3 year timeframe. They have also been in contact with several potential investors and are currently working with a subset of these towards an investment within a year. They are also currently working on an application for the Danish Advanced Technology Foundation.

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

3.2 Individual Publications Resulting from these Achievements

In certain cases publications that also are relevant for this activity has instead been presented in the corresponding cluster deliverable without being listed here.
ULUND


TU Braunschweig


UPC

UYork
The publications from UYork can be found in the corresponding cluster activity reports.

KTH


**IPPorto**


Nikoliç B., Awan M. A., Petters S.M., “Comparing the Schedulers and Power Saving Strategies with SPARTS”, Published at Open Demo Session of Real-Time Techniques and Technologies of the 32nd IEEE Real-Time Systems Symposium (RTSS@Work), Vienna, Austria, December 2011

**IMEC**


Blanch, C.; Baert, R.; Coene, P; D'Hondt, M.; Ma, Z. and Wuyts, R. “Runtime Scheduling for Video Decoding on Heterogeneous Architectures”. In *RTNS Conference (Real-Time and Network Systems) 2011*, Nantes, France.


**TUKL**


VERIMAG
The publications from Verimag can be found in the corresponding cluster activity reports.

DTU


Michael Reibel Boesen, Jan Madsen and Didier Keymeulen. *A reconfigurable hardware architecture for high-reliability applications*. Submitted to Transactions on Aerospace and Electronic Systems.


UPorto


SSSA


UPM

ETHZ
Pratyush Kumar, Lothar Thiele: Thermally optimal stop-go scheduling of task graphs with real-time constraints. ASP-DAC 2011: 123-128.

UNIBO

-- The above are new references, not present in the Y3 deliverable --

3.3 Joint Publications Resulting from these Achievements
Enrico Bini, Giorgio Buttazzo, Johan Eker, Stefan Schorr, Raphael Guerra, Gerhard Fohler, Karl-Erik Årzén, Vanessa Romero Segovia, Claudio Scordino, “Resource Management on Multicore Systems: The ACTORS Approach”, IEEE Micro, 31:3, pp. 72-81, May 2011. http://doi.ieeecomputersociety.org/10.1109/MM.2011.1. (Since the content of the article is quite broad and not only applies to adaptivity it has also been included in the OS and Networks cluster deliverable)


Javier Silvestre, Ricardo Marau, Paulo Pedreiras, Luis Almeida. “On-line QoS Management for Multimedia Real-Time Transmission in Industrial Networks”, IEEE Transactions on Industrial Electronics, 58(3):1061-1071. DOI: 10.1109/TIE.2010.2049711, March 2011. (this work was referred last year but was finally published this year, only)


Rui Santos, Paulo Pedreiras, Moris Behnam, Thomas Nolte, Luis Almeida. A Demonstration of Hierarchical Scheduling over Ethernet. RTSS@Work session of RTSS 2011, Vienna, Austria, November 29, 2011.


-- The above are new references, not present in the Y3 deliverable --

### 3.4 Keynotes, Workshops, Tutorials

#### Keynotes
Keynote: Fast and accurate system-level model of a NoC-based MPSoC supporting real-time applications

Leandro Soares Indrusiak, University of York
International Symposium on System-on-Chip, Tampere, Finland – November 1st 2011

Abstract: The talk presented a simulation model for Multiprocessor Systems-on-Chip based on Network-on-Chip which can obtain metrics for communication latency two orders of magnitude faster than state-of-the-art simulators. It is particularly useful to evaluate the impact of dynamic and adaptive task mapping approaches.

Courses and Tutorials

Tutorial: Temperature-aware Scheduling
Lothar Thiele, ETH Zurich
ARTIST Summer School, September 4-9, 2011, Aix-les-Bains, France

Abstract: Power density has been continuously increasing in modern processors, leading to high on-chip temperatures. A system could fail if the operating temperature exceeds a certain threshold, leading to low reliability and even chip burnout. There have been many results in recent years about thermal management, including (1) thermal-constrained scheduling to maximize performance or determine the schedulability of real-time systems under given temperature constraints, (2) peak temperature reduction to meet performance constraints, and (3) thermal control by applying control theory for system adaption. The presentation will cover challenges, problems and approaches to real-time scheduling under temperature constraints for single- as well as multi-processors.

Tutorial: Control for Embedded Systems
Karl-Erik Årzén, ULU ND
ARTIST Summer School China, August 8-12, 2011, Beijing, China

Abstract: The aim of the course was to give an overview of embedded control systems and of the use of control techniques in computer software systems.

Course Modules:


Tutorial: Real-Time Communication in Embedded Systems

Luis Almeida, UPorto

ARTIST Summer School China, August 8-12, 2011, Beijing, China

Abstract: Distributed real-time systems are becoming pervasive, either in process control, factory automation and more recently, embedded systems. This course will present an introduction to computer networks from a real-time systems perspective. The lectures include an initial presentation of general concepts in networks and then focus on the physical and data link layers, devoting particular attention to the medium access control. Then, the course will address the issue of traffic scheduling and its relationship with medium access control, showing typical schedulability analysis that can be used to derive a priori guarantees of traffic timeliness. A few paradigmatic protocols will then be presented and analyzed, including a reference to the growing interest on wireless communication. Finally, the course will address a few related on-going research efforts, mainly towards flexible real-time communication for adaptive and reconfigurable systems.

Workshops and Special Sessions


The APRES series of workshops on adaptive and reconfigurable embedded systems with Luis Almeida (UPorto) and Karl-Erik Årzén (ULUND) being members of the steering committee is one of the major events of this activity. The third workshop received 20 submissions including papers for oral presentations and abstracts for demos from which 9 papers were selected together with 4 demos. The workshop attracted 29 participants. The keynote was given by Prof. John Knight from the University of Virginia, Charlottesville, USA.

URL: http://www.artist-embedded.org/artist/Overview,2331.html


Objective: Performance and resource management in computing systems is increasingly important in everything from server systems in data centers to embedded systems. During recent years the use of feedback control techniques has attracted an increased attention both in academia and industry as a means for for realizing this. The objective of this workshop was to gather leading researchers in the field from both the control amd the computing communities and create an environment for cross-fertilization and new ideas.

Organizers:

• Karl-Erik Årzén, ULUND
Participants: 55 participants including 27 invited speakers. In addition to the organizers several members of the cluster were represented and gave invited presentations incl, Luca Benini (UNIBO), Gerhard Fohler (TUKL), Enrico Bini (SSSA), Karl Henrik Johansson, Bo Wahlberg and Rolf Stadler (KTH), Johan Eker and Jimmie Håkansson (Ericsson). Industrial participation from IBM, Microsoft, Vm Ware, HP Labs, Advertising.com Group, in addition to Ericsson.


This year Karl-Erik Årzén from this activity was the program chair of ECRTS.

URL: http://www.cister.isep.ipp.pt/ecrts11/

Conference track: Trach on Cyber-Physical Systems at RTSS, Vienna, Austria, Nov30 – Dec 2, 2011

Karl-Erik Årzén was program chair for the track on cyber-physical systems at RTSS.

Workshop: Reconfigurable and Communication-centric Systems-on-Chip (ReCoSoC), Montpellier, France, June 20-22, 2011

Leandro Soares Indrusiak, University of York was the program chair.

Invited Lectures and Presentations

Invited Presentation: Control Aspects in Adaptive Video Streaming

(Gerhard Fohler, TUKL)

LCCC Workshop on Control of Computing Systems, Lund Sweden, Dec , 2011

Abstract: Early real-time systems dealt with simple, periodic tasks, with known behavior, for which full guarantees could be given. In modern systems and applications, however, unpredictable resource demands have to be met by unpredictable resource demands. An example is video decoding, which fluctuating resource demands, due to frame content and encoding methods, to be handle on multi core platforms, where bus contention from shared caches impacts processing times significantly.

In the talk, we will discuss methods to adress such issues via a resource managment framework based on simple abstractions and system-wide arbitration. In particular, we will pose questions about control aspects related to the video adaptation, including granularity, possibility of oscillations, stability. Example of video adaption will serve to visualize the effects.

Invited Presentation: Managing SoCs beyond their Thermal Design Power: Model-Predictive Control and Model Learning
Abstract: The current trend in mobile computing is to design MPSoC platforms with negative thermal margins: their die can dissipate (in a sustainable way) significantly more than the thermal design power of its package and cooling system. Such an apparently suicidal policy is dictated by market pressure from the smart phone and tablet markets: the CPU of new platforms are marketed based on their peak clock frequency, as maximum-speed sequential execution is required for a few critical use cases (e.g. first-time loading of script-rich web page). As a consequence we need to learn how to manage platforms which are inherently thermally unstable. The talk will review advanced thermal management techniques based on model learning and model predictive control, and delve into implementation challenges and promising hardware-software evolutions which can help us address the looming thermal crisis.

Invited Presentation: Feedback Control in Mobile Phones and Telecom Systems
(Johan Eker, Ericsson)

Abstract: In modern cell phones the user experience is highly dependent on how well resources are managed. Many applications are competing for CPU resources, memory, sensors, screen estate etc., often resulting in a non optimal behavior. By introducing high level resource management we believe that the user experience can be improved while at the same time reduce power consumption and heat dissipation. Feedback is a key component in achieving this. A demo implementation on a Android based terminal is discussed.

Invited Presentation: Control Aspects in Adaptive Multicore CPU Management
(Karl-Erik Årzén, ULUND)

Abstract: The adaptive resource management framework implemented in the European ACTORS project is presented. A resource manager has been developed that collaborates with a new Linux scheduler providing support for hard constant bandwidth server reservations, in order to adapt applications to changes in resource availability and to adapt the resource allocation to changes in application requirements. The focus of this talk is the three demonstrators developed based on the framework. The demonstrators presented are an adaptive video quality demonstrator, a feedback control demonstrator, and a video decoding demonstrator. All of these execute under the control of the resource manager.
Invited presentation by Martin Törngren related to the mode management and architecture achievement.

-- The above is new material, not present in the Y3 deliverable --
4. Overall Assessment and Vision for the Transversal Activity

4.1 Final Overall Assessment

During the four years of ArtistDesign significant results have been achieved in a number of areas of relevance for adaptivity in embedded systems. The majority of the work falls within the general area of adaptive resource management, in particular of CPU resources, but significant work has also been performed in the areas of adaptive networking and adaptive hardware.

4.1.1 Selected Highlights

A short summary of the some of the highlights of the work can be found below:

- **Scheduling analysis**: Efficient and effective scheduling analysis for fixed priority systems has been developed that allows adaptivity, in the sense of tasks arriving and leaving the system, to be accommodated. The emphasis of this work is to maximise the utilisation of the available resources by adapting near optimal algorithms. Additionally, a new method for allocation and scheduling of parallel tasks in soft-real time systems (multimedia decoding) in the presence of post-silicon, process and ageing induced variability in a nominally homogeneous target multi-core platform has been developed. In this context an efficient online policy for meeting timing constraints with minimum energy has been proposed and demonstrated.

- **Memory**: Adaptable memory architectures based upon scratchpads for supporting dynamic real-time process loads have been developed, where the control of when data is moved can change with the actual dynamic behaviour of the application.

- **Collaboration frameworks**: An adaptable cooperation-based framework for networked embedded systems with heterogeneous nodes has been developed, which allows constrained devices to cooperate with more powerful (or less congested) neighbors, to meet allocation requests and handle stringent constraints, opportunistically taking advantage of global resources and processing power. Service allocation is performed by time-bounded distributed QoS-aware services, which are able to trade-off computation time and resource usage for the quality of achieved results.

- **Service adaptation**: Techniques have been developed for adapting the service request handling behaviour to the specific requirements of the services in Service Oriented Architectures (SOA). CPU contracts are used to ensure sufficient computation time for dealing with services with special requirements. The framework, which also supports multicore hardware, runs of top of a modified version of the Linux kernel that provides CPU budgets. Related to this techniques have been developed in order to perform quality compositions of services at design and execution time as a means for adaptation of, and decision making on, which services/components to use and how.

- **Run-time resource management**: An adaptive resource manager for distributed embedded systems aimed at multimedia applications, e.g., broadcast management systems, was developed. Considerable savings in power consumption, hardware cost and system size were reported in an industrial case study. Parallel to this a QoS based adaptive resource management system for homogeneous multicore platforms was developed. The approach is based on partitioned CBS bandwidth servers in combination with control and optimization techniques and is executing on top of Linux.
The approach is mainly developed for soft real-time applications, e.g. multimedia, modelled with dataflow networks, but has also been applied to feedback control applications. The latter approach has also been extended to network-based video streaming applications (MPEG-2 and MPEG-4) as well as has been ported to Android.

Related to the above a new method for synthesizing adaptive controllers for real-time applications has been developed. Here algorithms are parameterized by quality levels which impact the QoS and the execution times. The controller computes optimal values of the quality levels online, i.e. values that allow the highest QoS while meeting the real-time constraints. To cope with uncertain execution times a fine-grained controller that is constantly adapting the chosen quality levels depending on the actual time and on a combination of average and worst-case estimates of the execution times is used.

- **Run-time analysis**: A distributed approach for in-system run-time performance analysis of embedded systems has been developed. The embedded analysis engine is complemented by a framework that enables access control and runtime-optimization through the use of distributed algorithms that allow the usage of self-configuration services for self-protecting real-time systems.

- **Sensor networks**: New approaches to adaptive energy management of energy harvesting system using solar cells have been developed. Based on a prediction of the future available energy, the application parameters are adapted in order to maximize the utility in a long-term perspective. A formal model of the corresponding optimization problem has been formulated. The problem is solved using multiparametric programming to precompute the application parameters offline for different environmental conditions and system states. Related to this an optimal algorithm has been derived for scheduling the tasks within the sensor nodes that jointly handles constraints from both the energy and time domain. This is combined with an admittance test that decides for arbitrary task sets, whether they can be scheduled without deadline violations. The latter is based on the concept of energy variability characterization curves (EVCC) which captures the dynamics of various energy sources.

- **Control techniques**: A new method for optimizing the timing parameters of real-time control tasks in resource-constrained embedded systems has been derived. Also, new feedback scheduling techniques and new event-driven sampling mechanisms have been proposed. The latter results show that adaptive and non-periodic sampling schemes are an interesting new technique for meeting the demands imposed by modern embedded systems.

- **Adaptivity in networks**: Here various ways of adapting a communication channel to varying application requirements or environmental conditions to enhance the efficiency of medium utilization have been proposed. For controlled access networks with isolated virtual channels the guaranteed bandwidth and latency can be adapted online using the Flexible Time-Triggered (FTT) paradigm on switched Ethernet, either with COTS switches (FTT-SE protocol) or enhanced ones (FTT-enabled switch). For uncontrolled access networks, e.g., wireless networks, a method based on a TDMA round that adapts its phase to escape away from interfering traffic while restructuring the round in a dynamic number of slots equal to the current number of active nodes has been developed.

- **Programmable hardware**: A new type of ultra fault tolerant FPGA named the eDNA architecture has been conceived all the way from development of the concept, to the implementation of a prototype, to test in a space related case study NASA JPL.
• **WCET analysis**: Parametric WCET bounds, where the WCET bound depends on the values of certain inputs, can be used in adaptive real-time systems where the scheduling of tasks adapts to external factors such as varying data sizes affecting the running times of tasks. A general method for parametric WCET analysis, which combines a number of advanced symbolic techniques including relational abstract interpretation, counting of integer points in polyhedra, and parametric integer programming has been developed and implemented in the WCET analysis tool SWEET.

• **Reference architectures**: A reference architecture for automotive embedded systems that addresses the needs for flexible and automatic run-time reconfiguration has been proposed. The research focus was the development of technical support in terms of middleware services for a closed adaptation of distributed embedded systems. In addition to the reference architecture an information model of the control parameters that represent the target system configuration alternatives, environmental parameters, and internal conditions has been defined and a functional design has been performed.

4.1.2 **Metrics**

The long-term vision for this activity on the 4-year horizon was to generate a substantial advance in theory, methods and tools of relevance to adaptivity in embedded systems and to disseminate this into industry and to the scientific community at large. In this we have been very successful, e.g.,

• 45 joint publications related to adaptivity in embedded systems have been generated.
• 133 individual publications related to adaptivity in embedded systems have been generated.
• 19 workshops or technical meetings have been organized.
• 8 educational events have been organized
• The partners have a large amount of industrial contacts, some of them created solely due to ArtistDesign.
• Several companion projects have been started during the realm of ArtistDesign.

--- The above is new text, not present in the Y3 deliverable ---
4.2 Assessment for Year 4

The assessment of the work that has been performed within the activity continues to be positive. Several workshops and meetings have been organized by the partners. The meetings act as the interface between the different clusters on issues related to embedded system adaptivity. The partners work on a number of challenging research issues, both individually and together, in the latter case often within the umbrella of STREP projects. The partners have contributed to education about adaptive and feedback-based approaches. There are also several contacts between industry and academia within the activity, e.g., collaborations involving STM, Ericsson, IMEC, Denso, and Evidence just to name a few.

During the year the main workshops organized were APRES 2011 and the Workshop on Control of Computing Systems coorganized with LCCC. During 2012 we will continue along these lines with the fourth APRES workshop in conjunction with CPSWEEK 2012.

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

4.3 Indicators for Integration

The indicators for integration for Year 4 in the Year 3 report were as follows:

- At least 10 joint publications
  - During Year 4, 14 joint publications were reported. The goal was well met.
- More than 10 research collaborations
  - In Section 3.1, 10 research collaborations are reported. The goal was met.
- More than 10 meetings or workshops organized by the partners.
  - Only five workshops or technical meetings were organized. Hence, the goal has not been met. However, a large number of meetings and workshops of partial relevance to adaptivity were organized by the thematic clusters of ArtistDesign and by the ordinary projects involving the partners of this activity.
- Two educational events.
  - Three tutorials or short courses were organized by the members at Artist summer schools. The goal has been met
- The completion of a joint white paper on Adaptivity in embedded system.
  - This goal has not been met. However, a special session on Adaptive Embedded Systems of RTSJ guest-edited by Årzén is currently in the reviewing process. Several of the papers are co-authored by members of this activity. Also, there are plans to generate a book out of the presentations from the Workshop on Control of Computing Systems in which several of the partners participated.

-- Changes wrt Y3 deliverable --
This section has been updated compared to Year 3.
4.4 Future Directions

In the future, adaptivity towards changes in the environment will become even more important. Keywords that describe this trend are trustworthy computing and mixed criticality requirements. An increased demand can be foreseen for verification methods of adaptation policies and mechanisms and for robust designs. The role of feedback for managing resources has been identified. New models and algorithms as well as primitives in the embedded systems to apply them, will be needed. It is important to advance the knowledge in verifiable adaptive control of complex systems. Nowadays, control loops at various system levels interact with mostly unknown results in terms of guaranteed system properties, e.g. timing behavior and temperature.

The use of adaptivity and feedback to provide performance and robustness in embedded systems becomes more natural, the more complex and hard to statically analyze the systems are. Since increased complexity and heterogeneity in addition to an ever increasing amount of software is one of the most prominent trends in embedded systems today we are convinced that adaptive techniques will be increasingly important for the future.

In addition to the adaptivity of embedded systems with respect to changing task properties and environmental changes, we are increasingly faced with non-functional properties such as power and temperature. A major challenge we are facing is how to change system properties such as operation voltage and on-off behaviour in order to guarantee an upperbound on the temperature of a multiprocessor system. At the same time, guarantees on the timeliness of operation must be given. Control strategies are needed that are either based on off-line information or take into account on-line measurements on task arrivals, execution times and temperatures (if available). Many of these concerns embedded systems share with more general server systems and data centers supporting, e.g., cloud applications. Also here power consumption and temperature control issues must be integrated with balancing of the computing load.

Although ArtistDesign ends, the network and collaboration that the NoE has established will continue. Some examples are:

- Adaptivity in embedded systems was one of the topics of a COST proposal submitted by the partners from the OS and Network cluster. Although the proposal was not successful in the first round a new proposal will be submitted during Spring 2012.
- TUKL and ULUND will continue their joint work on adaptive resource management initialised by the ACTORS project.
- Enrico Bini from SSSA will spend two years at ULUND as a Marie Curie fellow starting in March 2012, working on cyber-physical system topics and also collaborating with Ericsson.
- The collaboration between Ericsson, UIUC and ULUND on resource management in telecommunication systems will continue.
- Adaptivity in embedded systems was one of the topics of a COST proposal submitted by the partners from the OS and Network cluster. Although the proposal was not successful in the first round a new proposal will be submitted during Spring 2012.
- MDH and Tidorum will continue their collaboration around bit-precise abstract relational domains, and parametric WCET analysis, within the APARTS project.
- The close interaction between ETH and UBologna will continue.

-- The above is new text, not present in the Y3 deliverable --
5. Transversal Activity Participants

-- Changes in the Cluster Participants wrt Y3 deliverable --

The partner description of IMEC has been updated. Chantal Ykman-Couvyreur has replaced Maja D’hondt as the team leader for IMEC.

5.1 Core Partners

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<tr>
<th>Transversal Activity Leader &amp; Team Leader</th>
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<tbody>
<tr>
<td>Professor Karl-Erik Årzén</td>
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<td>Lund University</td>
</tr>
<tr>
<td>URL: <a href="http://www.control.lth.se/user/karlerik/">http://www.control.lth.se/user/karlerik/</a></td>
</tr>
</tbody>
</table>

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, feedback applied to computer systems

Role in leading conferences/journals/etc in the area
Co Chair 4th Intl. Workshop on Feedback Control Implementation and Design in Computing Systems & Networks (FeBID 2009)
Co Chair Workshop on Adaptive Resource Management (WARM 2010)
Program Chair of Euromicro Real-Time Systems Conference 2011 (ECRTS’11)

Notable past projects
HRTC, CHEM, 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

Further Information
Leader for the cluster for Control for Embedded Systems in Artist2 (2005-2008)
<table>
<thead>
<tr>
<th>Team Leader</th>
<th></th>
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</thead>
</table>
| Prof. Gerhard Fohler  
Technical University of Kaiserslautern (TUKL)  
URL: [www.eit.uni-kl.de/fohler](http://www.eit.uni-kl.de/fohler) | |
| Technical role(s) within ArtistDesign | 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 analysis 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, sub track 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”  
| Awards / Decorations | Best paper award, ECRTS 2008 |
| **Team Leader**  
**Activity Leader for “Real-Time Networks”** |
| --- |
| ![Image](image1.png) Prof. Luis Almeida  
University of Aveiro  
URL: [http://www.ieeta.pt/lse](http://www.ieeta.pt/lse) |
| **Technical role(s) within ArtistDesign** | Leader of the team from the University of Aveiro. |
| **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 accompanying 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.  
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 maximizing the utilization of system resources.  
CIDER, Communication Infrastructure for Dependable and Evolvable Real-time systems. The project pursued two objectives: to analyze 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.  
| **Awards** | Best Paper Award in WFCS 2004  
Best Paper Award in SICICA 2000 |
### Team Leader

| Technical role(s) within ArtistDesign | Member of the Strategic Management Board  
Co-leads Hardware Platforms and MPSoC Design  
Participates in Intercluster activity: Design for Adaptivity  
Participates in Intercluster activity: Design for Predictability and Performance  
Leader of the JPRA Activity: “Platform and MPSoC Design” |
|-------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

### Research interests

(i) Development of power modeling and estimation framework for systems-on-chip.  
(ii) Development of optimal allocation and scheduling techniques for energy-efficient mapping of multi-task applications onto multiprocessor systems-on-chips.  
(iii) Development of energy-scavenging techniques for ultra-low power sensor network platforms.

### Role in leading conferences/journals/etc in the area

- Program chair and vice-chair of Design Automation and Test in Europe Conference.  
- Member of the 2003 MEDEA+ EDA roadmap committee 2003.  
- Member of the IST Embedded System Technology Platform Initiative (ARTEMIS); working group on Design Methodologies  
- Member of the Strategic Management Board of the ARTIST2 Network of excellence on Embedded Systems  
- Member of the Advisory group on Computing Systems of the IST Embedded Systems Unit.  
- Member of the technical program committee and organizing committee of several technical conferences, including the Design Automation Conference, International Symposium on Low Power Design, the Symposium on Hardware-Software Codesign. He is Associate Editor of the IEEE Transactions on Computer-Aided Design of Circuits and Systems and of the ACM Journal on Emerging Technologies in Computing Systems.  
- Fellow of the IEEE.

### Notable past projects

- **ICT-Project REALITY - Reliable and variability tolerant system-on-a-chip design in more-moore technologies.** Funded under 7th FWP (Seventh Framework Programme). ICT-2007.3.1 Next-Generation Nanoelectronics Components and Electronics Integration. Start date: 01/01/2008; Duration: 30 months; Contract Type: Collaborative project; Project Reference: 216537; Project Cost: 4.45 million euro; Project Funding: 2.9 million euro.

- **ICT-Project PREDATOR - Design for predictability and efficiency.** Funded under 7th FWP (Seventh Framework Programme).
Programme). ICT-2007.3.3 Embedded Systems Design. Start date: 01/02/2008; Duration: 36 months; Contract Type: Collaborative project; Project Reference: 216008; Project Cost: 3.93 million euro; Project Funding: 2.8 million euro.

ICT-Project **GALAXY - interface for complex digital system integration**. Funded under 7th FWP (Seventh Framework Programme). ICT-2007.3.3 Embedded Systems Design. Start date: 01/12/2007; Duration: 36 months; Contract Type: Collaborative project; Project Reference: 214364; Project Cost: 4.08 million euro; Project Funding: 2.9 million euro.


ICT-Project **SHARE - Sharing open source software middleware to improve industry competitiveness in the embedded systems domain**. Funded under 7th FWP (Seventh Framework Programme). ICT-2007.3.7 Network embedded and control systems. Start date: 01/05/2008; Duration: 24 months; Contract Type: Coordination and support actions; Project Reference: 224170; Project Cost: 1.1 million euro; Project Funding: 590000.00 euro.

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**Team Leader**

| Photo | Prof. Eduardo Tovar  
Polytechnic Institute of Porto (ISEP-IPP), Porto (Portugal)  

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**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 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**

Executive Board Member of the Euromicro Technical Committee on
Transversal Activity: Design for Adaptivity

<table>
<thead>
<tr>
<th>conferences/journals/etc in the area</th>
<th>Real-Time Systems.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Program Chair ECRTS’05, RTN’02, WDES’06.</td>
</tr>
<tr>
<td></td>
<td>General Chair of WFCS’00, ECRTS’03.</td>
</tr>
<tr>
<td></td>
<td>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.</td>
</tr>
</tbody>
</table>


| Further Information | Senior Member of IEEE |

<table>
<thead>
<tr>
<th>Technical role(s) within ArtistDesign</th>
<th>Activity leader for “Timing Analysis”</th>
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<tbody>
<tr>
<td></td>
<td>Timing analysis, program analysis.</td>
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</table>

| Research interests | Timing analysis, static program analysis, language design for embedded and real-time systems, program transformations, parallelism |

| Notable past projects | FP7 STREP ALL-TIMES, Integrating European Timing Analysis Technology (coordinator). http://www.all-times.org |
|                       | Several national projects, funded by Swedish Research Council, VINNOVA, KKS, SSF, Ericsson |

Prof. Björn Lisper (Mälardalen University)
http://www.idt.mdh.se/personal/blr/
### Team Leader

<table>
<thead>
<tr>
<th>Technical role(s) within ArtistDesign</th>
<th>Undertakes research in real-time systems scheduling, particularly for flexible systems. Also concerned with the development of programming languages for this domain.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research interests</td>
<td>Scheduling, languages, modeling and formal logics.</td>
</tr>
<tr>
<td>Role in leading conferences/journals/etc in the area</td>
<td>Previous Chair of the IEEE Technical Committee on Real-Time Systems. Edited special issue of ACM Transactions on Embedded Systems (on education).</td>
</tr>
<tr>
<td>Notable past projects</td>
<td>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 work on temporal aspects of dependability.</td>
</tr>
<tr>
<td></td>
<td>FIRST – EU funded project concerning flexible scheduling</td>
</tr>
<tr>
<td></td>
<td>FRESCOR – EU follow on project to FIRST</td>
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</table>

### Team Leader

| Technical role(s) within ArtistDesign | Main areas of research: Embedded Systems and Software  
Artist2 activities and role: Communication Centric Systems: Formal Performance Analysis, Linking Simulation and Verification, Design Space Exploration of Embedded Systems |
<table>
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<tbody>
<tr>
<td>Team Leader</td>
<td>Lothar Thiele (ETH Zurich)</td>
</tr>
<tr>
<td>Research interests</td>
<td>Research interests include models, methods and software tools for the design of embedded systems, embedded software and bioinspired optimization techniques.</td>
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<td>--------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Awards / Decorations</td>
<td>In 1986 he received the &quot;Dissertation Award&quot; of the Technical University of Munich, in 1987, the &quot;Outstanding Young Author Award&quot; of the IEEE Circuits and Systems Society, in 1988, the Browder J. Thompson Memorial Award of the IEEE, and in 2000-2001, the &quot;IBM Faculty Partnership Award&quot;. In 2004, he joined the German Academy of Natural Scientists Leopoldina. In 2005-2006, he was the recipient of the Honorary Blaise Pascal Chair of University Leiden, The Netherlands. Chair of ACM SIGBED.</td>
</tr>
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</table>

**Team Leader**

| Prof. Giorgio Buttazzo |
| Scuola Superiore Sant'Anna (SSSA), Pisa (Italy) |
| URL: [http://fanean.sssup.it/~giorgio/](http://fanean.sssup.it/~giorgio/) |

<table>
<thead>
<tr>
<th>Technical role(s) within ArtistDesign</th>
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<tbody>
<tr>
<td>Coordinating the cluster on Operating Systems and Network and the activity entitled &quot;Resource-Aware Operating Systems&quot;.</td>
</tr>
<tr>
<td>Providing support on real-time scheduling, operating systems, resource management, overload handling, energy aware algorithms, and quality-of-service strategies.</td>
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<table>
<thead>
<tr>
<th>Research interests</th>
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<tbody>
<tr>
<td>Real-time operating systems, dynamic scheduling algorithms, quality of service control, multimedia systems, advanced robotics applications, and neural networks.</td>
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<table>
<thead>
<tr>
<th>Role in leading conferences/journals/etc in the area</th>
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</thead>
<tbody>
<tr>
<td>Executive Board Member of the Euromicro Conference on Real-Time Systems.</td>
</tr>
<tr>
<td>Program Chair of RTSS'01, ECRTS'03, EMSOFT'04, HSCC'07.</td>
</tr>
<tr>
<td>General Chair of RTSS'02, EMSOFT'04, ECRTS'07.</td>
</tr>
<tr>
<td>Program committee member of most real-time related conferences.</td>
</tr>
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<table>
<thead>
<tr>
<th>Notable past projects</th>
</tr>
</thead>
</table>
### Awards

- 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

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**Team Leader in Activity: Design for Adaptivity**

<table>
<thead>
<tr>
<th>Technical role(s) within ArtistDesign</th>
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<tbody>
<tr>
<td>A. Jantsch contributes to KTH participation and to the work on formal models of computation and communication and the ForSyDe framework. Furthermore, he also contributes to Hardware Platforms and MPSOC Design with focus on run-time environments and analysis techniques.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Research interests</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Jantsch’s main research topics are models of computation, modelling and analysis of embedded systems and SoCs, networks on chip.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Notable past projects</th>
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</thead>
<tbody>
<tr>
<td><strong>ANDRES</strong> (Analysis and Design of run-time Reconfigurable, heterogeneous Systems) Project – EU FP6 (<a href="http://andres.offis.de/">http://andres.offis.de/</a>)</td>
</tr>
<tr>
<td><strong>SPRINT</strong> (Open SoC Design Platform for Reuse and Integration of IPs): EU FP6 (<a href="http://www.ecsi-association.org/sprint">http://www.ecsi-association.org/sprint</a>)</td>
</tr>
</tbody>
</table>

Professor Axel Jantsch
KTH
http://web.it.kth.se/~axel/
MOSART (Mapping Optimization for Scalable multi-core ARchiTecture) – EU FP7 (http://www.mosart-project.org/)

Team Leader

Jan Madsen (Technical University of Denmark)

Main areas of research: Embedded Systems Design and Modeling
Artist2 activities and role: System Modelling Infrastructure, Communication-Centric, Systems, Design for Low-Power

Research interests

Research interests include high-level synthesis, hardware/software codesign, System-on-Chip design methods, and system level modeling, integration and synthesis for embedded computer systems.

Role in leading conferences/journals/etc in the area

He is Program Chair for DATE07. He has been Tutorial Chair and Program Vice Chair for DATE06, Workshop Chair for CODES+ISSS’05, General Chair of CODES ‘01 and Program Chair of CODES ‘00. He is on the editorial board of the journal “IEE Proceedings – Computers and Digital Techniques”

Awards / Decorations

In 1995 he received the Jorck’s Foundation Research Award for his research in hardware/software codesign

Team Leader

Senior researcher Chantal Ykman-Couvyvreur
IMEC vzw.
http://www.imec.be

Representing IMEC Smart Systems and Energy Technology division in:
-Cluster: SW Synthesis, Code Generation and Timing Analysis
Cluster: Operating Systems and Networks
-Cluster: Hardware Platforms and MPSoC Design
-Intercluster activity: Design for Adaptivity
-Intercluster activity: Integration Driven by Industrial Applications

Research interests
Ch. Ykman-Couvreur is currently active in run-time management for embedded multi-core platforms

Role in leading conferences/journals/etc in the area
Ch. Ykman-Couvreur has published in International Journals and Conferences. She is active on several program committees of international conferences and in the organization of international workshops.

Notable past projects
Responsible for following FP7 European projects:
GENESYS (http://www.genesys-platform.eu)
2PARMA (http://www.2parma.eu)
COMPLEX (http://complex.offis.de)
PHARAON

5.2 Affiliated Industrial Partners
Ericsson and NXP are affiliated industrial partners. They are, however, described in the corresponding thematic cluster deliverables.

5.3 Affiliated Academic Partners

Activity Leader for “Qos-aware components”
Prof. Alejandro Alonso
Universidad Politécnica de Madrid.
URL: http://www.dit.upm.es/aalonso

Technical role(s) within ArtistDesign
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 for 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. |

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**Core Teamleader JPRA Activity “Design of Adaptivity”**

| Technical role(s) within ArtistDesign | Core Teamleader in Platform and MpSoC Design, Platform and MpSoC Analysis, Design for Adaptivity, Integration Driven by Industrial Applications.  
Affiliated Teamleader in Design for Predictability and Performance |
| Research interests | Research interests include embedded architectures, hardware/software co-design, design automation, real-time systems, and embedded systems engineering. |
| Role in leading conferences/journals/etc in the area | Rolf Ernst chaired major international events, such as the International Conference on Computer Aided Design of VLSI (ICCAD), or the Design Automation and Test in Europe (DATE) Conference and Exhibition, and was Chair of the European Design Automation Association (EDAA). He is a founding member of the ACM Special Interest Group on Embedded System Design (SIGBED), and was a member of the first board of directors. He is an elected member (Fachkollegiat) and Deputy Spokesperson of the “Computer Science” review board of the German DFG (corresponds to NSF). He is an advisor to the German Ministry of Economics and Technology for the high-tech entrepreneurship program EXIST |
**Team Leader**

![Image](https://via.placeholder.com/150)

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

**Technical role(s) within ArtistDesign**

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: 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.  
Design issues and protocols for wireless sensor networks and networked embedded systems.

**Research interests**

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.

**Role in leading conferences/journals/etc in the area**

Program Chair of SOCNE 2010, HSI’09, ETFA 08, ETFA 05.  
WIP Chair of ETFA 09, SIES 07, ETFA 06.  
General Chair of ECRTS 04.  
On the PC of many editions of ECRTS, RTSS, RTAS, WFCS, ETFA, RTN , FET, RTNS, WTR.  

**Notable past projects**

Italian National projects  
PRIN 04 entitled “Study and development of a real-time land control and monitoring system for fire prevention”,  
COFIN 01 entitled "High-Performance Processing for Applications with High-Intensity Computational Requirements and Real-Time Constraints, both funded by the Italian Ministry of University and Research.
Further Information

- Responsible for the University of Catania of the flexWARE Project, Flexible Wireless Automation in Real-Time Environments, www.flexware.at, a STREP Project funded by the European Commission within the 7 FP.
- Involved in standardization activities as Member of the International Electrotechnical Commission (IEC), Technical Committee SC65C, as member of:
  - Working Group 17, dealing with Coexistence in Wireless Industrial communication networks.
  - Working Group 11, Real-Time Industrial Ethernet (RTE).
- Senior member of the IEEE since June 2009.
- Recipient of the IEEE Industrial Electronics Society 2008 Early Career Award.

Team Leader

- Dr. Pau Martí
  - Technical University of Catalonia, Barcelona, Spain
  - URL: http://esaii.upc.edu/people/pmarti/

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.

5.4 Affiliated International Partners

Tarek Abdelzaher and Lui Sha are affiliated international partners to this activity. They are, however, listed in the corresponding thematic cluster deliverables.
6. Internal Reviewers for this Deliverable

The reviewers for this deliverable are

- Pau Martí, UPC
- Martin Törngren, KTH