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

Transversal Activity Progress Report for Year 2

### Transversal Activity: Design for Adaptivity

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#### 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 Y2 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. Off-line adaptivity is required to handle changing 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 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 include 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 Y1 deliverable --

No changes with respect to Year 1.

#### 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).

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#### -- Changes wrt Y1 deliverable --

No changes with respect to Year 1, except for paragraph 3 which is new.

#### 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, 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 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 a 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 componentbased 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.

-- Changes wrt Y1 deliverable --

No changes with respect to Year 1.



### 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 bried 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 exonomically 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 reservationbased 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 Y1 deliverable --

No changes with respect to Year 1.



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

Adaptivity is a concern that 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 Y1 deliverable --

No changes with respect to Year 1.

#### 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 recently has started a new programme. 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 Y1 deliverable --

No changes with respect to Year 1.



#### 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), jointly organized educational events (Chapter 3), and the development of a common shared wiki that will act as the repository for the work.

#### -- Changes wrt Y1 deliverable --

No changes with respect to Year 1.

#### 2.5 Interaction of the Transversal Activity with Other Communities

The partners of the activity interact with a 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 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 FRESCOR, ACTORS, HiPEAC, PREDATOR, COMBEST, MOSART, ANDRES, REALITY, DySCAS, CHAT, FlexWARE, and MOSART.

#### -- Changes wrt Y1 deliverable --

No changes with respect to Year 1



### 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

#### Dynamic changes of real-time parameters (ETHZ, SSSA)

The collaboration between ETHZ and SSSA has been continued and there have been several related meetings. PhD student from SSSA Luca Santinelli has finished his visit at ETHZ. During his stay, several well-known server-based hierarchical scheduling strategies were described with real-time calculus. The next step is to make such scheduling strategies dynamic by allowing them to change their parameters online according to the current requirements of the applications while still meeting real-time constraints. This work is ongoing.

At the same time, ETHZ has continued the work on investigating the effects of changing task sets and real-time requirements while still guaranteeing real-time constraints. The approach [SPT09] presented at DATE'09 was restricted to single processor systems. This has been extended to distributed systems by using the theory of real-time interfaces. It has also lead to a computationally more efficient method for finding the mode transition parameters. The relevant publication was [ST09] presented at RTAS'09. It is relevant for many practical systems that have different operating modes. Furthermore, it is not a trivial to solve the problem because schedulability needs to be shown not only in the individual operating modes, but also during the transitions between the modes. In this work, they proposed an interface-based design approach based on Real-time interfaces which extends their previous work and makes it applicable to open dynamic environments and distributed systems.

#### Assignment of real-time parameters to control tasks (SSSA)

The Scuola Superiore Sant'Anna of Pisa investigated the problem of selecting task parameters for real-time controller tasks in resource-constrained systems. In particular, a general approach has beed proposed to derive a control performance loss index in either simulative or experimental way, with respect to various timing attributes. An optimization method has been finally proposed to assign task periods and deadlines that minimize the derived performance loss index. Extensive simulations have shown the effectiveness of the proposed methodology.

## Timing analysis and sampling mechanisms for event-driven control systems (UPC, SSSUP, ULUND)

Standard discrete-time control laws consider periodic execution of control jobs. Although this assumption simplifies the control design and the resource utilization analysis for later implementation, it leads to a conservative usage of computing resources. On the contrary, event-driven control offers controllers with tighter resource utilization. However, job executions are no longer periodic, and predicting their computing requirements is crucial for efficient implementation in severely limited computing systems. Work has been carried out for



characterizing the different type of sampling intervals that even-driven controllers generate, which range from chaotic behaviors to periodic oscillatory patterns [VMB09a]

For several control loops sharing limited computing resources, a key design aspect is to efficiently select the controllers' sampling periods. Recent results indicate that controllers' execution rates must be different from those provided by the standard static periodic sampling approach, either tackling the problem of sampling period selection using feedback scheduling techniques or event-driven control techniques. Within the context of event-driven control systems, work has been carried out to investigate a new sampling scheme based on Lyapunov functions [VMB09b]. This sampling mechanism has been studied when control loops share a single processor and in the networked control systems (NCS) setting [YLVMF09].

This work also has strong connections to the work on sporadic event-based control performed by ULUND. The latter is, however, reported in the activity deliverable on Scheduling and Resource Management.

#### QoS-aware cooperative embedded systems (IPPorto)

The main goal of the project is to provide an adaptable framework for embedded systems with heterogeneous nodes, by allowing constrained devices to cooperate with more powerful (or less congested) neighbours, to meet allocation requests and handle stringent constraints, opportunistically taking advantage of global resources and processing power. Cooperation is achieved via the formation of dynamic, temporary coalitions of nodes, which, due to their higher flexibility and agility, are capable of effectively respond to new, challenging requirements. Service allocation is performed by time-bounded distributed QoS-aware services, which are able to trade-off computation time and resources for the quality of achieved results.

In the research year 2, the project specified mechanisms for the decentralised adaptation of service characteristics in a distributed collaborative environment, and started the evaluation of middleware for supporting adaptive cooperative embedded systems [NP09] [NPC09]..

#### Temporal isolation in real-time systems (IPPorto)

Systems which host applications of different criticality are becoming increasingly pervasive. Examples are mobile phones, which are simultaneously running applications with temporal constraints, like voice communication and video streams, alongside those having best effort character like email clients. Many of such systems allow programs to be installed post deployment rendering an a-priori analysis impossible. Traditional models like fixed priority tend to lead to starvation, while fairness based approaches do not provide sufficient isolation. Within this activity work has been carried out on integrating the analysis into the deployed OS as well as provide an operating system which is able to support fair and timely provision of execution time to applications.

In this year work has been carried out on a holistic model allowing many low level effects like interrupts, cache-related preemption delay etc. to be considered in on-line analysis and at run-time.

#### Wireless technologies for automation (University of Catania)

The University of Catania is a partner of the flexWARE project. flexWARE (flexible Wireless Automation in Real-Time Environments) is a STREP project coordinated by the Austrian Academy of Sciences, Vienna, Austria, launched on 1st Sept. 2008 for a period of 36 months under the FP7 in the field of Information and Communication Technologies. The intention of the project is to make wireless technologies suitable for automation and industrial needs and, hence, to develop adequate infra-structure to provide secure and reliable wireless communications with real-time capabilities and mobility through the whole factory. flexWARE



aims to implement a novel secure middleware between the physical communication and the application which will be designed with special respect to security, flexibility and mobile, realtime enabled nodes that can roam between the Access Points of the system. The outcome of the project will open possibilities for more efficient production processes and plants due to its flexibility and scalability. Moreover it is likely that this proposed project will influence science as well as the market due to the savings for (re-)cabling and maintenance as well as new opportunities as factory wide maps of goods. Project web site: www.flexware.at

## Adaptive topology management to combine energy efficiency and QoS in WSNs (University of Catania)

Topology management protocols play an important role in WSNs, managing the sleep transitions of the nodes to make data transmissions occur in an energy-efficient way, thus prolonging network lifetime. The previous year, University of Catania proposed a novel approach to cope with the clashing requirements of energy efficiency and real-time performance, based on the idea of separating the energy and delay requirements by addressing them at different levels of the protocol stack. This approach is based on the combination of an energy-efficient topology management protocol with a non-energy-aware routing protocol enforcing a real-time behaviour in data forwarding. However, classical topology management protocols are not suitable for real-time WSNs, as they may introduce unbounded delays. For this reason, a topology management protocol was specifically designed for realtime WSNs which are able to provide bounded delay and routing fidelity. This year the topology management protocol has been extended by introducing adaptive mechanisms that allow for both event-driven data transmission and dynamic network (re-) configuration [LT09]. In particular, the support for aperiodic transmissions has been improved, a dynamic clustering algorithm has been adapted to effectively set-up the AUs when the density of nodes is nonuniform and a novel energy balancing feature has been introduced to significantly increase the overall network lifetime through a node exchange policy. Both the effectiveness of the energy balancing technique and the beneficial effect on the performance of the routing protocol running on top of such a topology management protocol have been confirmed by ns-2 simulations.

#### Theory of distributed performance analysis (TU Braunschweig)

The distributed compositional performance analysis model and algorithm developed in the previous year has been extended by distributed algorithms covering convergence detection and distribution of data, e.g. path latencies within the model. Additionally, a theory describing convergence properties of the centralized as well as the distributed implementation of compositional performance analysis has been established. This theory gives rise to an approach on computing a bound on the response time of compositional performance analysis, if a bound for local schedulability analysis can be given. As a first step, an evaluation of the possibilities of bounding the runtime of the standard busy-window approach to schedulability analysis has been performed together with a study of the effects on the accuracy of the results.

#### In-system self-optimization for real-time systems (TU Braunschweig)

In the last year the approach of self-protecting real-time system to support autonomous assignment of execution priorities under consideration of timing properties has been extended. A distributed heuristic algorithm for the constraint satisfaction problem (CSP) of finding feasible priority assignments in static priority preemptive (SPP) scheduled hard real-time systems has been developed. The heuristic considers end-to-end latency constraints in arbitrary non-cyclic application graphs mapped on arbitrary platform graphs. The algorithm can be implemented completely distributedly allowing usage as self-configuration service in distributed embedded systems.



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

Due to the increased need for fault-tolerant systems, several reconfigurable self-healing hardware platforms have emerged in the last decade. The contribution of eDNA distinguishes itself by being on a higher level of logical granularity and consequently, lowering the cost of implementing large scale systems.

The eDNA platform consists of multiple processors (called cells) interconnected through a NoC. The key to the eDNA platform is the "eDNA" (electronic DNA) which is the medium with which the user programs the platform. The eDNA is simply a behavioural specification of the algorithm the user wants to implement encoded in a binary format such that the cells can read it. The cells self-organise by translating the behavioural specification into a task-graph using a software-to-hardware translational model. Finally, the cells map the task using a mapping strategy called a "growing pattern". The self-healing is implemented by rerunning the self-organisation algorithm. This migrates tasks to healthy cells. eDNA is aimed at becoming a new type of fault-tolerant coarse-grained FPGA [BM09].

## Adaptive energy management in clusters of wireless sensor nodes (University of Bologna, ETHZ)

In Y2, UoB and ETHZ have addressed energy efficiency for wireless smart camera networks which is one of the major efforts in the distributed monitoring and surveillance. In a distributed wireless sensor network, several nodes cooperate to the achievement of a global goal. The monitored environment is generally covered by multiple nodes deployed in the environment in order to guarantee redundancy and overlapping of the sensed area. In many scenarios each node is able to modulate and adjust the monitored area by varying the sensitivity of on-board sensors. UoB and ETHZ have designed a simple but optimal power management tailored for multi-modal video sensor nodes and based on model predictive controller (MPC) principles. The aim is to show how an adaptive controller helps the system to improve its performance while outperforming naive power management policies. The system is designed for low-power and low-cost video surveillance and exploits small solar cells for battery recharging and Pyroelectric InfraRed (PIR) sensors to provide low-power monitoring when the camera is not needed [MBTB09]. An effective power management has been developed to allow the design of small sized and perpetually powered devices [MTBDB09].

#### Adaptive control of MPEG-2 decoding (TUKL, ULUND)

Decoding MPEG-2 streams in resource constrained system faces the challenges of matching varying resource demand (due to MPEG-2 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.

During Year 2 a first controller has been extended with additional stream adaptation methods based on subframe level elements for a wide range of granularities [GF09].

#### A reference architecture for self-configuring embedded systems (KTH, Volvo, Offis)

As part of the DySCAS research project, a framework and middleware architecture for the development of dynamically or self-configurable systems are being developed. Dynamic configuration refers to the ability of a system to during run-time change the number of components (software/hardware), their connections and the properties which characterize their execution and communication. In contrast, in a traditional static configuration these parameters are determined during development time and mainly remain fixed during the operation of the system. The following use cases drive the work: Download of new software, attachment of



external devices, and internal reconfiguration for performance or fault-tolerance purposes. It should be noted that the self-configuration is delimited to the application related software and hardware. The middleware supports dynamic configuration but is itself not reconfigurable during run-time. The work involves ArtistDesign partners KTH, Offis and Volvo (affiliated) and non ArtistDesign partners such as Enea, Bosch, Daimler and the Univ. of Greenwich. The work has through the assistance of ArtistDesign included interactions with Aveiro, CEA and LTH (partners of ArtistDesign). Currently, a functional architecture in terms of a component model definition, middleware components and interfaces have been developed and defined. Algorithms suitable for run-time configuration management, load balancing and quality of service have been developed. While the project mainly targets automotive applications (starting with telematics/infotainment domains), the architecture is general enough to be able to serve other applications as well. Automotive specifics include the consideration of standards (Autosar), safety critical functionality, integration with legacy systems and resource constraints. The architecture and algorithms have been evaluated in simulation and evaluation in terms of a reference implementation is under way. Modeling and validation as part of this framework is treated in the corresponding ArtistDesign activities.

During Year 2, further work in the DySCAS project has focused on refining and evaluating the reference architecture into a middleware technology to facilitate context-aware dynamic adaptation of automotive embedded systems, [ACTSS09], [CTFPQ09], [ACPPT09]. The DySCAS approach exploits the fundamental principles of automatic control. At system runtime, the DySCAS middleware services provide support for monitoring the status of applications and resources and for detecting relevant events, e.g. mode switches, deadline misses or node failure. If needed, appropriate adaptation (e.g. triggering an application to switch to a different QoS mode, redeploying an application to another node) is performed. In a DySCAS system, the management and control decisions are carried out hierarchically based on embedded system meta-data and adaptation policies/rules. Such system meta-data provide built-in knowledge about system configurability and adaptability, and is the basis for any embedded configuration management decisions. DySCAS provides an information-model to support the design of adaptation meta-data and policies/rules. The issues of particular concern include impacts of changes on the overall system functionality, end-to-end performance, and dependability. The specified information may include, e.g., the application's maximum need of processor, memory and communication resources, as well as task timing parameters and overall system merit/benefit in each QoS mode. The developed reference architecture has been evaluated through reviews, formal verification, simulation, and by developing a few implementations, [CTFPQ09],

Work related to Dyscas on verification/validation and modeling is reported separately in the corresponding deliverables. See <u>www.dyscas.org</u> for more information on the DySCAS project.

#### Reference implementations of self-configuring embedded systems (KTH)

As part of the DySCAS project, a set of reference implementations and demonstrators have been built to investigate technology constraints and provide proof-of-concept implementations of the Dyscas proposed middleware technology. These include the DyLite (DySCAS Lite/QoS) prototype systems, [PGFQCT09], [P09]. The focus of the implementation was to build a low-overhead, simple implementation of the main concepts in the DySCAS reference architecture. Its primary purpose is to validate the parts of the DySCAS system closely related to the (re-)configuration algorithms and quality of service (QoS) mechanisms, and as a basis for the demonstrator built on a previously developed scale truck model developed in the Mechatronics lab (in cooperation with Scania and Enea). The DyLite implemented has confirmed that the DySCAS ideas are implementable in real middleware. The DyLite implementation is very compact - the footprint is only 15 kB - which clearly makes it deployable even in very small-scale microcontrollers. DyLite supports most of the DySCAS use-cases, focusing on



reconfiguration and QoS aspects. It was early on decided that DyLite would not support runtime program down-load and load balancing through actual run-time migration of code (load balancing is supported but only through preallocation of software components to several nodes). Two reasons for these delimitations included the small microprocessors used and the fact that another DySCAS demonstrator focused on such use cases.

## Adaptive and feedback-based resource management in FRESCOR and ACTORS (York, SSSA, ULUND, TUKL, Evidence, Ericsson, Cantabria)

Several of the partners from the OS and Networks cluster work together in the two STREP projects FRESCOR and ACTORS. The main objective of FRESCOR (FP6) is to develop the enabling technology and infrastructure required to effectively use the most advanced techniques developed for real-time applications with flexible scheduling requirements, in embedded systems design methodologies and tools, providing the necessary elements to target reconfigurable processing modules and reconfigurable distributed architectures.

ACTORS (FP7 project coordinated by Ericsson) addresses design of resource-constrained software-intensive embedded systems with high requirements on adaptivity and efficiency. Three techniques will be combined: virtualization, feedback control, and data-flow programming models.

During Y2 FRESCOR was successfully completed and ACTORS is in a very hectic phase in which a lot of the basic functionality is being implemented. As a result of this the number of ACTORS related publications is currently very small. One of the highlights was the release of the new SCHED\_EDF scheduler from Evidence for the Linux platform.

FRESCOR: <u>http://www.frescor.org/</u>

ACTORS: <u>http://www.actors-project.eu/</u>

#### Feedback control of web-servers (ULUND)

An important factor for a user of web sites is the duration of time between the request for a web page until an answer has been returned. If this response time is too long, the user is likely to abandon the web site and search for other providers of the service. To avoid this loss of users, it is important for the web site operator to assure that users are treated sufficiently fast. On the other hand, it is also important to minimize the effort to optimize profit. As these objectives often are contradictory, an acceptable target response-time can be formulated. The resources are allocated in a manner that ensures that long response times do not occur, while, at the same time, using as little resources as possible to not overprovision.

The work performed at ULUND takes a control-theoretic perspective to solve this problem [KKR09] [K09]. The resources are considered as the control input, and the response time as the main output. Several disturbances affect the system, such as the arrival rate of requests to the web site. A testbed was designed to allow repeatable experiments with different controller implementations. A server was instrumented with sensors and actuators to handle requests from 12 client computers with capability for changing work loads.

On the theoretical side, a model of a web server has been developed. It explicitly models a specific sensor implementation where buffering occurs in the computer prior to the sensor. As a result, the measurement of the arrival rate becomes state dependent under high load. This property turns out to have some undesirable effects on the controlled system. The model is capable of predicting the behavior of the testbed quite well. Based on the presented model, analysis shows that feed-forward controllers suggested in the literature can lead to instability under certain circumstances at high load [KR09].



#### Parametric WCET analysis (MDH)

The work on parametric WCET analysis, initiated with USaar, has been carried on further [BEL09]. A new method for parametric WCET analysis has been developed, which uses a symbolic technique for counting the number of states in different program points. A major achievement is a novel symbolic computation method, which for a minor loss of precision gives orders of magnitude of speedup and reduced memory consumption as compared with earlier methods. This breaks a barrier as regards the scalability of the analysis. The method has also been applied in a case study of a robotics control system.

#### Dynamic behavior of embedded systems (IMEC, NTNU, NTUA)

Today's embedded systems operate under increasingly dynamic conditions. They have to support unpredictable interaction with users or with the environment. And they should work with widely varying input data, downloadable software, online services, and a wider range of software applications than is traditionally supported by embedded systems. Worst-case system designs take into account all this unpredictability upfront, resulting in overallocated resources, higher costs and longer time-to-market. In addition, embedded systems that are connected in a network also have to deal with the dynamism and unpredictability of distributed systems, further increasing the design challenges. This forces designers of embedded systems to consider alternatives to the traditional design methods.

IMEC examines methods to optimally exploit the flexibility offered by modern hardware platforms and networks. These have the hardware that is needed to implement a more dynamic behavior: multiple heterogeneous processing cores, including general-purpose processors. And in a distributed setting, the number and variety of available processing elements is even larger. This allows more flexibility to select processing resources for executing software, not only at design time, but also at run time. The goal of IMEC is to create a run-time resource manager that addresses the dynamically changing conditions and makes a trade-off between processing availability and type, communication bandwidth, power consumption, or any other relevant constraint, while meeting the required quality of service. Advanced infrastructure offers techniques such as virtualization, managed code, just-in-time compilation and optimization.

#### Model-based implementation of real-time applications in BIP (Verimag)

The objective of this work is to develop a model-based implementation method for BIP programs. The method uses a Real-time Execution Engine with an abstract notion of time. The Engine adapts program execution so as to ensure correct implementation according to a formal notion of time-safety.

This work is a step towards rigorous implementation of adaptive scheduling policies.

One important result is the implementation method can be summarized as follows:

An abstract model of the application software based on timed automata is considered. The model takes into account only platform-independent timing constraints expressing userdependent requirements. The actions of the model are assumed to be timeless. Using timed automata allows general timing constraints (e.g. lower bounds, upper bounds, time nondeterminism). The abstract model describes the dynamic behavior of the application software as a set of interacting tasks without restriction on their type (i.e. periodic, sporadic, etc.)

A second result is the introduction of a notion of physical model. This model describes the behavior of the abstract model (and thus of the application software) when it is executed on a target platform. It is obtained from the abstract model by assigning to its actions execution times which are upper bounds of the actual execution times for the target platform. The implementation method leads from a given physical model (abstract model and given WCET



for the target platform) under some robustness assumption, to a correct implementation. It is based on a Real-Time Execution Engine which respects the semantics of the abstract model. Furthermore, if robustness of models cannot be guaranteed, it can check online if the execution is correct, that is, if timing constraints of the model are met. In addition, it checks violation of essential properties of the abstract model properties such as deadlock-freedom, consistency of the timing constraints, etc.

The method allows safe and correct implementation of application software on an execution platform if the WCET for its actions define a time-robust assignment. The application software consists of a set of components modeled as timed automata and interacting by rendezvous. An interaction is a set of actions belonging to distinct components that must be synchronized. From a given state it can be executed only if all the involved actions are enabled. The method uses a Real-Time Execution Engine which ensures component coordination by executing interactions. The Real-Time Execution Engine proceeds by steps. It has been shown that the proposed implementation method is correct for time-robust execution time assignments.

This is work in progress that will be continued over Y3.

#### Modeling and analysis of adaptive systems (KTH, Offis)

As part of the FP7 ANDRES project (<u>http://andres.offis.de/</u>) KTH has further developed a method for modeling and analysing run-time reconfigurable systems. General adaptivity has been integrated into the modeling framework ForSyDe. During the last year the general concept has been apllied on run-time reconfigurable, FPGA based systems and several case studies, together with Offis and Thales Communication, has been conducted [SZJ+2009, ZSJ2009]. The project ANDRES has been concluded in September 2009 and Offis has initiated a spin-off company that plans to commercialise the Offis tools for SystemC based synthesis, that also support run-time reconfiguration as a result of the ANDRES project.

In cooperation with the Physica Institute at the Justus-Liebig University in Giessen, Germany, KTH has developed a run-time reconfigurable architecture and design methodology for the design of event detectors in particle physics experiments [LLK+2009,LKL+2009, LJJ+2009].

#### 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. Universidad Poltécnica de Madrid (UPM) is working towards techniques for adapting the service request handling behaviour to the specific requirements of the services. The approach taken is to user CPU contracts to ensure some computation time for dealing with services with special requirements. This approach has been integrated in the MORE middleware, by changing the DPWS stack and the MORE core services to detect such requests and use threads with CPU contracts to handle them [ASL09]. This framework runs of top of a modified version of the Linux kernel that provides CPU budgets.

#### Support for adaptivity in distributed systems (UPorto/UAveiro, CMU, Mallorca, MDH)

University of Porto (University of Aveiro) is working on adding support for adaptivity in distributed systems by integrating resource management capabilities in the networking equipment, namely in Ethernet switches. This allows enforcing timeliness properties and adaptation thereof without relying on the end nodes. The result is a higher integration capability



with respect to what is possible with current networking technologies, with an improvement in bandwidth utilization. This line of work is performed in collaboration with CMU, Mallorca and Malardalen

UPorto/UAveiro together with UPVLC also pursue work on adaptivity in distributed systems through centralized resource management. This line of work exploits the Flexible Time-Triggered paradigm to provide dynamic adaptations in a distributed system, promptly and consistently. During this period, new results were achieved in the scope of industrial video surveillance

#### Graceful degradation in real-time wireless protocols (UPorto/UAveiro)

Aveiro/UnivPorto started cooperation with University of Pittsburgh in the scope of the Reconfigurable and Adaptive TDMA protocol (RA-TDMA) to characterize the reconfiguration time upon the admission or elimination of a node in the team/cluster. Another collaboration was triggered with University of Zaragoza to add adaptive mechanisms to an existing wireless protocol to make it exhibit graceful degradation when in the presence of interference caused by alien traffic.

## Towards a wiki-based white paper on adaptive resource management (Most partners of the activity)

An initiative has been made to jointly write a wiki-based "white paper" on adaptive resource management (<u>http://www2.control.lth.se/ArtistAdapt/index.php/Main\_Page</u>) Although the content currently is far from complete our ambition is to continuosly extend this during the span of ArtistDesign. Our ambition is also to combine this with the wiki-based taxonomy on flexibility in distributed systems developed within the RT Networks activity.

#### Changes wrt Y1 –

The majority of the above is new material, not present in the Y1 deliverable. In the case material is repeated from Y1 the focus here is on what has been achieved during Y2.

#### 3.2 Individual Publications Resulting from these Achievements

To the largest extent we have avoided duplicating publications that are part of the thematic activities. In the case this has not been possible we have tried to explicitly indicate when a publication has been included more than once.

#### ETHZ

[SPT09] Nikolay Stoimenov, Simon Perathoner, Lothar Thiele: Reliable Mode Changes in Real-Time Systems with Fixed Priority or EDF Scheduling. DATE 2009.

[ST09] Nikolay Stoimenov and Lothar Thiele, Interface-based design approach for analysis of mode changes in distributed real-time systems, San Francisco, USA, Proceedings of the 15th IEEE Real-Time and Embedded Technology and Applications Symposium: Proceedings of Demos and Posters, April, 2009.

#### University of York

[EB] P. Emberson and I. Bate, Stressing Search with Scenarios for Flexible Solutions to Real-Time Task Allocation Problems, IEEE Transactions on Software Engineering, To Appear.



#### SSSA

[SLB09] N. Serreli, G. Lipari and E. Bini. Deadline assignment for component-based analysis of real-time transactions. Proceedings of the 2nd Workshop on Compositional Real-Time Systems, Washington, DC, USA, December, 2009.

[B09] E. Bini. Modeling Preemptive EDF and FP by Integer Variables. Proceedings of the 4th Multidisciplinary International Scheduling Conference, Dublin, Ireland, August 2009.

[BBW09] E. Bini, G. Buttazzo and Y. Wu. Selecting the minimum consumed bandwidth of an EDF task set. Proceedings of the 2nd Workshop on Compositional Theory and Technology for Real-Time Embedded Systems, Washington, DC, USA, December, 2009.

[BB09] E. Bini and G. C. Buttazzo. The Space of EDF Deadlines: the exact region and a convex approximation. Real-Time Systems 41(1): 27-51, 2009.

#### UPC

[YLVMF09] J. Yépez, C. Lozoya, M. Velasco, P. Martí and J.M. Fuertes. Preliminary Approach to Lyapunov Sampling in CAN-based Networked Control Systems. In 35th Annual Conference of the IEEE Industrial Electronics Society (IECON09), Porto, Portugal, November 2009.

#### IP Porto

[NP09] Nogueira, L., Pinho, L., "Time-bounded Distributed QoS-Aware Service Configuration in Heterogeneous Cooperative Environments", Published in Journal of Parallel and Distributed Computing 69 (2009), pp. 491-507

[NPC09] Nogueira, L., Pinho, L., Coelho, J., "Coordinated Runtime Adaptations in Cooperative Open Real-Time Systems", Published in the 7th IEEE/IFIP International Conference on Embedded and Ubiquitous Computing

[PLHE09] Petters, S.M. Lawitzky, M., Heffernan, R., Elphinstone, K. "Towards Real Multi-Criticality Scheduling" Published in the 15th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications, Beijing, China, August, 2009

#### **University of Catania**

[LT09] L. Lo Bello, E. Toscano, An adaptive approach to Topology Management in Large and Dense Real-Time Wireless Networks, IEEE Transactions on Industrial Informatics, Special Section on Communication in Automation, Vol.5, N.3, pp.314-324, ISSN: 1551-3203, IEEE Industrial Electronics Society, Piscataway, USA, Aug. 2009

#### TU Braunschweig

[NSSE10] Moritz Neukirchner, Steffen Stein, Harald Schrom and Rolf Ernst. A software Update Service with Self-Protection Capabilities. In Proceedings of the conference on Design, Automation and Test in Europe (DATE), Dresden, Germany, March 2010 (to appear)

#### **TU Denmark**

[BM09] Michael Reibel Boesen, Jan Madsen, eDNA: A Bio-Inspired Reconfigurable Hardware Cell Architecture Supporting Self-organisation and Self-healing, in the proceedings of the 2009 NASA/ESA Conference on Adaptive Hardware System (AHS-2009), July-August 2009.

#### University of Bologna

[MTBDB09] Magno, Michele, Tombari, Federico, Brunelli, Davide, Di Stefano, Luigi and Benini, Luca, Multimodal abandoned/removed object detection for low power video surveillance systems, in: 6th IEEE International Conference On Advanced Video and Signal Based Surveillance. AVSS2009, Genoa, Italy, pages 188-193, 2009



#### TUKL

[GF09a] Raphael Guerra, Gerhard Fohler, Video decoding for reduced jitter and improved resource usage, WRT09: XI Workshop de Tempo Real, Recife, PE, Brazil, May 2009.

[GF09b] <u>Raphael Guerra</u>, <u>Gerhard Fohler</u>, <u>A Gravitational Task Model with Arbitrary Anchor</u> <u>Points for Target Sensitive Real-Time Applications</u>, Real-Time Systems Journal, September 2009.

#### KTH

[PGFQCT09] Magnus Persson, Javier García, Lei Feng, Tahir Naseer Qureshi, DeJiu Chen, Martin Törngren. DyLite: Design, Implementation and Experiences of a Light-Weight Middleware for Adaptive Embedded Systems. Technical report, KTH, Stockholm, 2009, TRITA MMK 2009:06, ISSN 1400-1179, ISRN/KTH/MMK/R-09/06-SE

[P09] Magnus Persson. Adaptive Middleware for Self-Configurable Embedded Real-Time Systems. Licentiate thesis, KTH, Nov. 2009. KTH, School of Industrial Technology and Management, TRITA MMK 2009-21, ISBN 978-91-7415-495-5

[SZJ+2009] Ingo Sander, Jun Zhu, Axel Jantsch, Andreas Herrholzy, Philipp A. Hartmanny, and Wolfgang Nebel. High-level estimation and trade-off analysis for adaptive real-time systems. In Proceedings of the 16th Reconfigurable Architectures Workshop, Rome, May 2009.

[ZSJ2009] Jun Zhu, Ingo Sander, and Axel Jantsch. Buffer minimization of real-time streaming applications scheduling on hybrid CPU/FPGA architectures. In Proceedings of the Design and Test Europe Conference (DATE), April 2009.

[LLK+2009] Ming Liu, Zhonghai Lu, Wolfgang Kuehn, Shuo Yang, and Axel Jantsch. A reconfigurable design framework for FPGA adaptive computing. In Proceedings of the International Conference on ReConFigurable Computing and FPGAs, Cancun, Mexico, December 2009.

[LKL+2009] Ming Liu, Wolfganga Kuehn, Zhonghai Lu, and Axel Jantsch. Run-time partial reconfiguration speed investigation and architectural design space exploration. In Proceedings of the International Conference on Field Programmable Logic and Applications, Prague, Chech Republic, September 2009.

[LJJ+2009] Ming Liu, Axel Jantsch, Dapeng Jin, Andreas Kopp, Wolfgang Kuehn, Johannes Lang, Lu Li, Soeren Lange, Zhen'an Liu, Zhonghai Lu, David Muenchow, Vladimir Pechenov, Johannes Roskoss, Stephano Spataro, Qiang Wang, and Hao Xu. Trigger algorithm development on fpga-based compute nodes. In 16th IEEE NPSS Real Time Conference, Beijing, May 2009.

#### ULUND

[L09] Mikael Lindberg, Constrained online resource control using convex programming-based allocation, Fourth International Workshop on Feedback Control Implementation and Design in Computing Systems and Networks, April 16, 2009, San Francisco, California, USA

[KR09] Martin Ansbjerg Kjær, Anders Robertsson, Effects of Neglecting Buffers in Feed-Forward Design for Web Servers, Fourth International Workshop on Feedback Control Implementation and Design in Computing Systems and Networks, April 16, 2009, San Francisco, California, USA



[KKR09] Martin Ansbjerg Kjær, Maria Kihl, Anders Robertsson, Resource Allocation and Disturbance Rejection in Web Servers using SLAs and Virtualized Servers, IEEE Transactions on Network and Service Management, Accepted for publication

[K09] Martin Ansbjerg Kjær, Disturbance Rejection and Control in Web Servers, PhD thesis, Department of Automatic Control, Lund University, November 2009

#### MDH

[BEL09] Stefan Bygde, Andreas Ermedahl, and Björn Lisper. An Efficient Algorithm for Parametric WCET Calculation. in Patrick Kellenberger, ed. Proc. 16th International Conference on Real-Time Computing Systems and Applications (RTCSA'09), pages 13-21. Beijing, China, Aug 2009. Best paper award.

#### IMEC

[CNCC09] Couvreur, C.; Nollet, V.; Catthoor, F. and Corporaal, H.: Fast multi-dimension multichoice Knapsack heuristic for MP-SoC run-time manangement. In Journal ACM Transactions on Embedded Computing Systems (to appear in 2009). Also listed in the Scheduling and Resource Management deliverable.

[TMBDUDVC09] Trautmann, M.; Mamagkakis, S.; Bougard, B.; Declerck, J.; Umans, E.; Dejonghe, A.; Van der Perre, L. and Catthoor, F.: Simulation framework for early phase exploration of SDR platforms: a case study of platform dimensioning. In Design, Automation and Test in Europe, DATE 2009, Nice, France, April 20-24, (2009). Also listed in the Platform and MPSoC deliverable.

#### UPM

[ASL09] Alejandro Alonso, Emilio Salazar, Jorge López, "Improving Predictability in Service Oriented Architectures", IFAC *Workshop on Real-Time Programming*, Mrągowo, Poland, October, 2009

#### UPorto

The publications by UPorto are reported in the RT Networks deliverable.

-- The above are new references, not present in the Y1 deliverable --

#### 3.3 Joint Publications Resulting from these Achievements

[MVFB10] P. Martí, M. Velasco, J. M. Fuertes, and G. Buttazzo. Design of an embedded control systems laboratory experiment. IEEE Transactions on Industrial Electronics, to appear.

[CMVB09] A. Camacho, P. Martí, M. Velasco and E. Bini. Implementation of Self-triggered Controllers. 15th IEEE Real-Time and Embedded Technology and Applications Symposium (demo session), San Francisco, CA, April 2009.

[VMB09a] M. Velasco, P. Martí, E. Bini. On Lyapunov Sampling for Event-driven Controllers. Proceedings of the 48th IEEE Conference on Decision and Control, Shanghai, China, December 2009.

[VMB09b] M. Velasco, P. Martí and E. Bini. Equilibrium Sampling Interval Sequences for Event-driven Controllers, Proceedings of the European Control Conference, Budapest, Hungary, August 2009.



[MVB09] P. Martí, M. Velasco and E. Bini. The Optimal Boundary and Regulator Design Problem for Event-Driven Controllers. Proceedings of the 12th International Conference on Hybrid Systems: Computation and Control, San Francisco, CA, April 2009.

[BBB09] E. Bini, M. Bertogna and S. Baruah. Virtual Multiprocessor Platforms: Specification and Use. Proceedings of the 30th IEEE Real-Time Systems Symposium, Washinghton, DC, USA, December 2009.

[MBTB09] Magno, Michele, Brunelli, Davide, Thiele, Lothar and Benini, Luca, Adaptive Power Control for Solar Harvesting Multimodal Wireless Smart Camera, in: in Third ACM/IEEE International Conference on Distributed Smart Cameras (ICDSC 2009), Como (Italy), 2009

[ACTSS09] Richard Anthony, DeJiu Chen, Martin Törngren, Detlef Scholle, Martin Sanfridson, Achim Rettberg, Tahir Naseer Qureshi, Magnus Persson and Lei Feng. Autonomic Middleware for Automotive Embedded Systems. Autonomic Communication, Vasilakos, A.V.; Parashar, M.; Karnouskos, S.; Pedrycz, W. (Eds.): 169-210. Springer US. ISBN: 978-0-387-09752-7.

[CTFPQ09] DeJiu Chen, Martin Törngren, Lei Feng, Magnus Persson. Tahir Naseer Qureshi, Richard Anthony, Mariusz Pelc et. al. Deliverable D2.3 (V1.0). Dynamically Self-Configuring Automotive Systems - DySCAS. STREP, European Commission FP6 Project no. FP6-IST-2006-034904. 2009. <a href="http://www.dyscas.org">http://www.dyscas.org</a>

[ACPPT09] Richard Anthony, DeJiu Chen, Mariusz Pelc, Magnus Persson and Martin Törngren. Context-Aware Adaptation in DySCAS. Electronic Communications of the EASST. Volume 19: Context-Aware Adaptation Mechanism for Pervasive and Ubiquitous Services 2009. CAMPUS 2009. ISSN 1863-2122.

[MHMMKC09] Narasinga Rao Miniskar, Elena Hammari, Satyakiran Munaga, Stylianos Mamagkakis, Per Gunnar Kjeldsberg, Francky Catthoor: Scenario Based Mapping of Dynamic Applications on MPSoC: A 3D Graphics Case Study. In Embedded Computer Systems: Architectures, Modeling, and Simulation, 9th International Workshop, SAMOS 2009, Samos, Greece, July 20-23, (2009). Also listed in the Scheduling and Resource Management deliverable.

[BPMCSM09] Bartzas, A.; Peon, M.; Mamagkakis, S.; Catthoor, F.; Soudris, D. and Mendias, J.: Direct memory access usage optimization in network applications for reduced memory latency and energy consumption. In Journal of Embedded Computing, p.241-254, Vol.3, Issue 3, (2009). Also listed in the Scheduling and Resource Management deliverable.

[GPHVMBECC09] S.V. Gheorghita, M. Palkovic, J. Hamers, A. Vandecappelle, S. Mamagkakis, T. Basten, L. Eeckhout, H. Corporaal, F. Catthoor, F. Vandeputte, K. De Bosschere: A System Scenario based Approach to Dynamic Embedded Systems, ACM Transactions on Design Automation of Electronic Systems (TODAES), Volume 14, Number 1, (2009). Also listed in the Software Synthesis and Code Generation deliverable.

[BTKMCSS09] Baloukas, C.; Temmerman, M.; Keller, A.; Mamagkakis, S.; Catthoor, F.; Soudris, D. and Demeyer, S.: Abstract and concrete data type optimizations at the UML and C/C++ level for dynamic embedded software. In Book Chapter of Behavioral Modeling for Embedded Systems and Technologies: Applications for Design and Implementation, p.55-84, (2009). Also listed in the Software Synthesis and Code Generation deliverable.

-- The above are new references, not present in the Y1 deliverable --



#### 3.4 Keynotes, Workshops, Tutorials

#### Keynote : Real-Time Scheduling for Control Systems, (Enrico Bini SSSA)

17th International Conference on Real-Time and Network Systems RTNS 2009, *Paris, France – October 26<sup>th</sup>, 2009* 

The talk presents an overview of the techniques that can be used to design control systems taking performance requirements and schedulability constraints into account.

## Invited Talk : On-line Timing Analysis in Organic Computing and Self-healing Systems (Rolf Ernst, TU Braunschweig)

Symtavision NewsConference 2009.

Braunschweig, Germany - Oct 01, 2009

The SymTA/S NewsConference is an annual event organized by the Symtavision GmbH that brings together engineers, managers, technology experts and researchers in the field of embedded real-time systems. Rolf Ernst was invited to present current research results to this audience highlighted the demand for adaptive systems. *(see also see also activity report Platform and MpSoC Analyis)* 

http://www.symtavision.com/newsconference2009.html

## Keynote: Challenges in Adaptivity for Embedded Real-time Systems (Gerhard Fohler, TUKL)

Opening Event for Call on Embedded Systems of FIT-IT, a funding initiative of the Austrian Federal Ministry for Transport, Innovation, and Technology, Vienna, Austria, 2009 09 25

# Invited Talk : On verification and validation of real-time control systems: formal approaches vs simulation (Karl-Erik Årzén, ULUND) Caltech Workshop on Verfication and Validation

Pasadena, US – 23-24 September, 2009

The objective of the workshop was to bring together experts in control, computer science, and networking from academia, industry and US governmental agencies and promote exchange of ideas and establishment of interdisciplinary collaborations within the field of verification and validation.

http://www.cds.caltech.edu/~murray/wiki/Caltech\_Workshop\_on\_Verification\_and\_Validation

## Keynote: Adaptive solutions for the emerging reliability and multicore resource management challenges (S. Mamagkakis, IMEC)

### 2nd Workshop on Adaptive and Reconfigurable Embedded Systems - APRES 2009

Grenoble, France, October 11th, 2009 within ESWEEK 2009

In this talk, the reliability and resource management challenges of the emerging multicore platforms were discussed and the proposed adaptive solutions were evaluated.

http://www.artist-embedded.org/artist/Keynote.html

## Invited talk: Taming the Flexibility versus Safety Challenge in Distributed Embedded Systems (Luis Almeida, UPorto)

1st tubs.CITY Symposium, Tech. Univ. Braunschweig

Braunschweig, Germany - 1-3 July 2009



Focuses on the flexibility versus safety conflict and addresses several perspectives of flexibility as well as the techniques that were developed in Aveiro to support them.

http://city.tu-braunschweig.de/index.php/en/events/symposium-2009/workshops/embeddedcommunication-

## Invited talk: Has the time come to flexible safety-critical systems? (Luis Almeida, UPorto)

#### Final DySCAS Workshop

Brussels, Belgium - 18 February 2009

Raises awareness to the issues related with the flexibility versus safety conflict, the benefits that are associated with a combination of both aspects and the challenges in achieving such combination.

http://www.dyscas.org/final\_workshop.htm

#### Workshop : Fourth International Workshop on Feedback Control Implementation and Design in Computing Systems and Networks (FeBID 2009), Cyber-Physical Systems Week,2009

#### San Francisco, US – April 16, 2009

Traditional practice in performance modeling focuses on using a variety of techniques including mathematical modeling, simulation, and analysis to understand the behavior of systems for the purpose of better design and evaluation. As IT systems, networks, and services become increasingly complex, this task becomes ever more difficult. In recent years, there has been considerable success in applying feedback control theory to analyzing and designing run-time IT control systems. Feedback control theory complements traditional modeling by providing formal mechanisms to dynamically control behavior of systems at run-time.

The FeBID series of workshops offer a unique opportunity for researchers and practitioners to discuss recent and innovative results in applying control theory to controlling performance of computing systems and networks. It provides a forum to exchange ideas and experiences on practical control system design and implementation and to identify future directions and challenges in aligning feedback control techniques with traditional performance modeling and simulation. The workshop program consisted of one invited plenary talk and 12 submitted papers. The workshop was co-chaired by Karl-Erik Årzén (ULUND) and several of the members of this activity participated in the PC. The workshop was co-funded by Artist.

http://controlofsystems.org/febid2009/

## Workshop: Second Workshop on Adaptive and Reconfigurable Embedded Systems (APRES 09), Embedded Systems Week, 2009

#### Grenoble, France – October 11, 2009

This was the second workshop in the APRES series which is co-funded by Artist. It aims at discussing new and on-going research in the development and use of adaptive and reconfigurable embedded systems and gathering feedback from the embedded systems community at large. Of particular interest are new concepts and ideas for modeling and analyzing tradeoffs of embedded and real-time systems, novel algorithms and mechanisms to realize adaptation and reconfigurability, and experience reports with practical or industrial case studies. The workshop was co-organized by Luis Almeida, Karl-Erik Årzén (members of the activity), and Sebastian Fischmeister, Insup Lee, and Juilan Proenza (non-members), with several of the Artist partners in the programming committee. The workshop contained 12 submitted paper and Stylianos Mamagkakis of IMEC gave a very appreciated plenary



presentation. The number of participants at the workshop was around 25. The papers of the workshop will be published by SIGBED Review.

http://www.artist-embedded.org/artist/Overview,1765.html

#### Course: ARTIST Graduate Course on Embedded Control Systems

Pisa, Italy – June 8-12, 2009

The fifth annual ARTIST Graduate Scool on Embedded Control Systems was organized and delivered by Giorgio Buttazzo and Mauro Marinoni (SSSA), Karl-Erik Årzén and Anton Cervin (ULUND), Paolo Gai (Evidence), Luis Almeida (UPorto), and Paulo Pedreiras (UAveiro).

The objectives of the course were to:

- Introduce the most important concepts and methodologies used to develop a real-time embedded system, including fundamentals of real-time scheduling, control and distributed systems;
- Show how to apply these concepts to develop simple real-time control applications using an embedded platform specifically developed for education.

http://www.artist-embedded.org/artist/Overview,1673.html

#### **Meeting: Annual Activity Meeting**

#### Pisa, Italy - April 2-3, 2009

Objectives for the meeting: Organize the activities during Year 2. Present the adaptive resource management related activities in FRESCOR, ACTORS, DysCAS together with the work at UPC/SSSA, DTU, and IMEC.

Organizer: Karl-Erik Årzén (ULUND) & Giorgio Buttazzo (SSSA)

Participating groups: ULUND, SSSA, TUKL, University of York, IMEC, UPorto, KTH, UPC, UPM, UCatania, DTU, UCantabria, Universidad Carlos III de Madrid, NXP, IPP Conclusions:

- The structure for a wiki-based white paper on embedded system adaptivity was outlined and set up. Initial contents were added.
- It was decided that the activity should take the initiative to an one-day workshop on adaptive resource management to be held in conjunction with the Cyber-Physical Systems Week in Stockholm, Sweden in April 2010. This should also constitute the annual activity meeting for 2010.

Web site: http://www2.control.lth.se/ArtistAdapt/index.php/Main Page/Meetings/Pisa Apr 2009

#### Meeting : BIP – DOL, 13<sup>th</sup> Oct. 2009

#### Grenoble, France

Objectives for the meeting: The main goal of this meeting was to introduce the available execution platforms of the DOL framework and try to find a suitable one for BIP. Organizer: Verimag

Other participants: Verimag, ETHZ

Conclusions : There are three execution platforms available from the DOL framework, i.e., the SHAPES platform, the broad band cell engine, and the DOL/MPARM simulator. It was concluded that the DOL/MPARM is suitable for the BIP timed model.

#### Meeting: Real-time Parameters, 1<sup>st</sup> Oct. 2009

Zurich, Switzerland



Objectives for the meeting: Establish a set of server-based resource-reservation strategies and their suitability for dynamic reconfigurations in resource-constraint systems. Organizer: ETHZ

Other participants: ETHZ, SSSA

Conclusions: The well-known server-based resource-reservation strategies are not designed to be adaptive therefore, new methods and strategies are needed that can guarantee resource-reservations during configuration changes. A new server-based strategy and a mechanism for reconfiguration have been proposed. This is currently investigated jointly by ETHZ and SSSA.

Meeting : DySCAS Open Workshop Brussels, Belgium – February 18, 2009 Objectives for the meeting: Dissemination of the results of the "Dynamically Self-configuring Automotive Systems" (DySCAS) FP6 project Organizer: Volvo (coorganised and funded by Artist) Conclusions : <u>http://www.artist-</u> embedded.org/docs/Events/2009/DySCAS/DySCAS%20workshop%20February%2018%20-%20Summary\_MT.pdf Web site: http://www.artist-embedded.org/artist/DySCAS-2009,1555.html

In addition KTH has had several meetings within the context of of the Dyscas project with Offis (ArtistDesign partner), Volvo (affiliated ArtistDesign partner), and Bosch, Daimler, Enea and Univ. of Grenwich.

-- The above is new material, not present in the Y1 deliverable --



### 4. Overall Assessment and Vision for the Transversal Activity

#### 4.1 Assessment for Year 2

The assessment of the work that has been performed during Year 2 is very positive. Several workshops and meetings have been organized by the partners. Of special importance was the general activity meeting in Pisa. These 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 level of participation among the partners in embedded FP6 and FP7 projects is very high. It can be expected that the number of collaborations and joint publications between the partners will increase during the coming years.

The partners have also contributed to education about adaptive and feedback-based approaches. This has been performed within summer schools or special courses. There are also several contacts between industry and academia within the activity, e.g., collaborations involving NXP, Ericsson, Volvo, IMEC, and Evidence just to name a few.

A major challenge for this activity is to integrate the more hardware-oriented partners from, e.g., the MPSoC cluster with the more software-oriented partners from the OS and networks cluster. Currently the activity is dominated by partners from the latter cluster.

The DySCAS project had a successful completion in March 2009. The project results received a lot of attention by researchers and in the press. A follow up proposal has been submitted for FP7, focusing on verification aspects of adaptive systems.

Also the FRESCOR project completed successfully during 2009.

During the year the activity has co-organized two open workshops, FeBID'09 and APRES'09, that both have been very successful. For 2010 we plan to continue along these lines with a workshop on Adaptive Research Management (WARM) in conjunction with the CPSWEEK 2010 in April.

-- The above is new text, not present in the Y1 deliverable --

#### 4.2 Overall Assesment since the start of the ArtistDesign NoE

The integration among the partners is demonstrated by the number of joint publications, projects and events organized within the cluster. The main examples are workshops, graduate courses, and the various research consortia that collaborate within, e.g. European embedded systems projects, like ACTORS, and PREDATOR. During Year 2 the positive development from Year 1 has continued.

-- The above is new text, not present in the Y1 deliverable --



#### 4.3 Indicators for Integration

The indicators for integration for Year 2 in the Year 1 were as follows::

- At least 10 joint publications
  - During Year 2 14 joint publications were reported. The goal was met.
- More than 15 research collaborations
  - In Section 3.1 only 9 research collaborations are reported. However, since several of them involve more than two partners it is unclear how they should be counted. Hence, it is not possible to say definitely whether the goal has been met or not.
- More than 10 meetings or workshops organized by the partners.
  - Seven workshops or meetings have been held. Hence, the goal has only partially been met.
- Three educational events.
  - Only one educational event was organized. Hence the goal has not been met.
- The content of the wiki will be substantially expanded.
  - The content of the wiki has been substantially expanded. The goal has been met.

The indicators for integration for Year 3 involve the following goals:

- At least 10 joint publications
- More than 10 research collaborations
- More than 10 meetings or workshops organized by the partners.
- Two educational events organized by the partners.
- The content of the wiki will be further expanded.

Hence, coampared to the indicators for Year 2 the goals have been somewhat reduced.

More specifically the individual partner's milestones for year 3 include the following items:

- SSSA will extend of the partitioning tool to support pipelining in multicore platforms.
- SSSA will support the integration of the partitioning tool with the TrueTime simulation enviroment.
- University of Porto will implement a prototype of the adaptive middleware for the QoS-Aware Cooperative Embedded Systems project.
- The APRES series of workshops has contributed to the networking among researchers in adaptive systems. It is likely that the activity will work for a continuation of this series for either the fall of 2010 or the Spring of 2011.
- ULUND will officially release a TrueTime version with support for multi-core scheduling.
- TUKL, SSSA, ULUND, and Ericsson will jointly implement an adaptive resource management system for dataflow applications executing on multi-core platforms within the ACTORS project, and evaluate it on different applications.

#### -- Changes wrt Y1 deliverable --

This section has been updated compared to Year 1.



#### 4.4 Long-Term Vision

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 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. New application domains are also emerging for adaptive systems, illustrated by, e.g., the iLAND project (one of the first Artemis projects: <a href="https://www.artemisia-association.org/iland">https://www.artemisia-association.org/iland</a>), applying adaptability to intelligent houses.

The long-term for this activity on the 4-year horizon is 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. Important issues include how to make trade-off in choosing the right level of Adaptivity and verification of adaptivity mechanisms to ensure they can be used in cost and mission critical system.

#### -- Changes wrt Y1 deliverable --

This section has been updated compared to Year 1.



### 5. Transversal Activity Participants

#### -- Changes in the Cluster Participants wrt Y1 deliverable -

The affiliation of Luis Almeida has been changed from University of Aveiro to University of Porto. The partner description of Lucia Lo Bello of University of Catania has been updated.

#### 5.1 Core Partners

Transversal Activity Leader & Team Leader		
	Professor Karl-Erik Årzén	
	Lund University	
	URL: http://www.control.lth.se/user/karlerik/	
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)	
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)	



Team Leader		
	Prof. Gerhard Fohler	
	Technical University of Kaiserslautern (TUKL)	
() A	URL: <u>www.eit.uni-kl.de/fohler</u>	
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	Chairman, technical committee on real-time systems, Euromicro	
conferences/journals/etc in the area	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"	
	FABRIC: Federated Applications Based on Real_time Interacting Components", IST-2001-37167 (2002-2003) investigated QoS management methods for home networks.	
Awards / Decorations	Best paper award, ECRTS 2008	



Team Leader		
C THE		
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. <u>http://www.ieeta.pt/atri/cambada/</u>	
	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. <u>http://www.ieeta.pt/lse/DISCO_web.pdf</u>	
	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. <u>http://www.hurray.isep.ipp.pt/activities/cider/</u>	
Awards	Best Paper Award in WFCS 2004	
	Best Paper Award in SICICA 2000	



Team Leader		
	Prof. Luca Benini, University of Bologna http://www-micrel.deis.unibo.it/%7Ebenini/	
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	<ul> <li>(i) Development of power modeling and estimation framework for systems-on-chip.</li> <li>(ii) Development of optimal allocation and scheduling techniques for energy-efficient mapping of multi-task applications onto multi-processor systems-on-chips.</li> <li>(iii) Development of energy-scavenging techniques for ultra-low power sensor network platforms.</li> </ul>	
Role in leading conferences/journals/etc in the area	<ul> <li>Program chair and vice-chair of Design Automation and Test in Europe Conference.</li> <li>Member of the 2003 MEDEA+ EDA roadmap committee 2003.</li> <li>Member of the IST Embedded System Technology Platform Initiative (ARTEMIS): working group on Design Methodologies</li> <li>Member of the Strategic Management Board of the ARTIST2 Network of excellence on Embedded Systems</li> <li>Member of the Advisory group on Computing Systems of the IST Embedded Systems Unit.</li> <li>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.</li> <li>Fellow of the IEEE.</li> </ul>	
Notable past projects	ICT-Project <b>REALITY</b> - <i>Reliable and variability tolerant system-</i> <i>on-a-chip design in more-moore technologies.</i> 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 <b>PREDATOR</b> - <i>Design for predictability and</i> <i>efficiency.</i> Funded under 7th FWP (Seventh Framework 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 <b>GALAXY</b> - <i>interface for complex digital system</i> <i>integration.</i> 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 <b>DINAMICS</b> - <i>Diagnostic Nanotech and Microtech</i> <i>Sensors.</i> Funded under 6th FWP (Sixth Framework Programme). FP6-NMP 'Nanotechnologies and nanosciences, knowledge-based multifunctional materials and new production processes and devices'. Contract Type: Integrated project; Project Reference:IP 026804-2. Start date: 01/04/2007. Duration: 18 + 30 months. Project Cost:7276856 Euro. Project Funding: 4499542 Euro. http://www.dinamics-project.eu/
ICT-Project <b>SHARE -</b> <i>Sharing open source software middleware</i> <i>to improve industry competitiveness in the embedded systems</i> <i>domain.</i> 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.

Team Leader	
	Dr. Stylianos Mamagkakis IMEC vzw. <u>http://www.imec.be</u>
Technical role(s) within ArtistDesign	Representing IMEC Nomadic Embedded Systems (NES) 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: Design for Predictability and Performance -Intercluster activity: Integration Driven by Industrial Applications
Research interests	Stylianos Mamagkakis received his Master and Ph.D. degree in Electrical and Computer Engineering from the Democritus Uni. Thrace (Greece) in 2004 and 2007, respectively. Since 2006, he



	coordinates a team of PhD students within the NES division at IMEC, Leuven, Belgium. His research activities mainly belong to the field of system-level exploration, with emphasis on MPSoC run-time resource management and system integration.
Role in leading conferences/journals/etc in the area	Stylianos Mamagkakis has published more than 35 papers in International Journals and Conferences. He was investigator in 9 research projects in the embedded systems domain funded from the EC as well as national governments and industry.
Notable past projects	Project leader of MNEMEE IST project <u>www.mnemee.org</u> Project leader of OptiMMA IWT project <u>www.imec.be/OptiMMA</u> Participation in: 1 international IMEC project (M4), 3 European IST projects (AMDREL, EASY, ARTIST2), 2 Greek projects (PRENED, DIAS)
Awards	1st prize in 'Technogenesis' Competition for Business Innovation, Greece, June'06 3rd prize in 'Otenet Innovation 2006' Competition for Business Innovation, Greece, November'06
Further Information	http://www2.imec.be/imec_com/nomadic-embedded-systems.php



Team Leader		
	Prof. Eduardo Tovar	
SPEE	Polytechnic Institute of Porto (ISEP-IPP), Porto (Portugal)	
	URL: <a href="http://www.hurray.isep.ipp.pt/asp/show_people.asp?id=1">http://www.hurray.isep.ipp.pt/asp/show_people.asp?id=1</a>	
1 Com		
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 conferences/journals/etc	Executive Board Member of the Euromicro Technical Committee on Real-Time Systems.	
in the area	Program Chair ECRTS'05, RTN'02, WDES'06.	
	General Chair of WFCS'00, ECRTS'03.	
	Program committee member in several editions of ERCTS, RTSS, RTAS, RTCSA, ICDCS, SRDS, WFCS, ETFA, EMSOFT and other IEEE, ACM and Euromicro events on real-time systems, embedded systems and factory communication systems.	
	Reviewer for Real-Time Systems, IEEE Transactions on Computers, ACM Transactions on Embedded Computing, IEEE Transactions on Industrial Informatics.	
Notable past projects	"REMPLI: Real-time Energy Management via Power-lines and Internet", NNE5-2001-00825 (2003-2006) investigated advanced scheduling and protocols for power-line communication systems (PLC).	
	"R-Fieldbus: High Performance Wireless Fieldbus in Industrial Multimedia-Related Environment", IST-1999-11316 (2001-2003), integrated advanced real-time mechanisms in hybrid wired/wireless fieldbus neworks. Mobility protocols and end-to-end deadlines	
	"CABERNET: Network of Excellence in Distributed Computing Systems Architectures", IST-2000-25088 (2001-2003).	
	"CIDER: Communication Infrastructure for Dependable Evolvable Real-time systems", POSI/1999/CHS/33139 (2001-2003), Portuguese Science Foundation project on real-time communication networks.	
Further Information	Senior Member of IEEE	



	Prof. Björn Lisper (Mälardalen University) http://www.idt.mdh.se/personal/blr/
Technical role(s) within ArtistDesign	Activity leader for "Timing Analysis" Timing analysis, program analysis.
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



Team Leader		
	Professor Alan Burns	
1 Lool	University of York, UK	
	URL: <u>www.cs.york.ac.uk/~burns</u>	
Technical role(s) within ArtistDesign	Undertakes research in real-time systems scheduling, particularly for flexible systems. Also concerned with the development of programming languages for this domain.	
Research interests	Scheduling, languages, modeling and formal logics.	
Role in leading conferences/journals/etc in the area	Previous Chair of the IEEE Technical Committee on Real-Time Systems. Edited special issue of ACM Transactions on Embedded Systems (on education).	
Notable past projects	DIRC – Dependability Interdisciplinary Research Collaborations – A large, UK, 6-year, multisite project looking at dependability of computer-based systems. Burns was a PI and managed the work on temporal aspects of dependability.	
	FIRST – EU funded project concerning flexible scheduling	
	FRESCOR – EU follow on project to FIRST	

Team Leader	
	Lothar Thiele (ETH Zurich)
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



Research interests	Research interests include models, methods and software tools for the design of embedded systems, embedded software and bioinspired optimization techniques.
Awards / Decorations	In 1986 he received the "Dissertation Award" of the Technical University of Munich, in 1987, the "Outstanding Young Author Award" of the IEEE Circuits and Systems Society, in 1988, the Browder J. Thompson Memorial Award of the IEEE, and in 2000- 2001, the "IBM Faculty Partnership Award". 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.

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



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

Team Leader in Activity: Design for Adaptivy	
	Professor Axel Jantsch KTH http://web.it.kth.se/~axel/
Technical role(s) within ArtistDesign	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.
Research interests	A. Jantsch's main research topics are models of computation, modelling and analysis of embedded systems and SoCs, networks on chip.
Role in leading conferences/journals/etc in the area	
Notable past projects	ANDRES (Analysis and Design of run-time Reconfigurable,



heterogeneous Systems) Project) – EU FP6 (http://andres.offis.de/)
<b>SPRINT (</b> Open SoC Design Platform for Reuse and Integration of IPs): EU FP6 (http://www.ecsi-association.org/sprint)
<b>MOSART</b> (Mapping Optimization for Scalable multi-core ARchiTecture) – EU FP7 (http://www.mosart-project.org/)

Team Leader	
	Jan Madsen (Technical University of Denmark)
Technical role(s) within	Main areas of research: Embedded Systems Design and Modeling
ArtistDesign	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

#### 5.2 Affiliated Industrial Partners

Ericsson and NXP are affiliated industrial partners. They are, however, described in the corresponding thametic cluster deliverables.



### 5.3 Affiliated Academic Partners

Activity Leader for "Qos-aware components"	
	Prof. Alejandro Alonso
	Universidad Politécnica de Madrid.
	URL: <u>http://www.dit.upm.es/aalonso</u>
Technical role(s) within	Activity Leader for "Qos-aware components"
ArtistDesign	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.

Core Teamleader JPRA Activity "Design of Adaptivity"	
	Prof. DrIng. Rolf Ernst (TU Braunschweig)
	http://www.ida.ing.tu-bs.de/en/home/faculty_and_staff/ernst/
Technical role(s) within	Core Teamleader in Platform and MpSoC Design, Platform and



ArtistDesign	MpSoC Analysis, Design for Adaptivity, Integration Driven by Industrial Applications.
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 (www.exist.org).

Team Leader	
	Prof. Lucia Lo Bello University of Catania (Italy) – Affiliated to SSSA, Pisa URL: <u>http://www.diit.unict.it/users/llobello/</u>
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,
	802 11 802 15 4 and Bluetooth networks
	Design issues and protocols for wireless sensor networks and
	networked embedded systems.
Posoarch interasts	Wireless networks and sensor networks, factory communication,
Research interests	real-time scheduling, overload handling, real-time industrial
	embedded systems, networked embedded systems, energy-aware
	protocols, automotive communications.
Role in leading	MUD Chair of ETEA 09 SIES 07 ETEA 06
conferences/journals/etc	General Chair of ECRTS 04
in the area	On the PC of many editions of ECRTS, RTSS, RTAS, WFCS,
	ETFA, RTN , FET, RTNS, WTR.
	Reviewer for several international journals, included the Real-Time
	Systems Journal, IEEE/IES Transactions on Industrial Informatics,
	EEE Transactions on industrial Electronics, ACM Transactions on Embedded Systems, IEEE Transactions on Education
	On the Editorial Board of the Journal of Real-time Image
	Processing, Springer, Germany.
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
	European project ESPRIT 26951 "NOAH - Network Oriented
	Application Harmonization.
Further Information	Responsible for the University of Catania of the flexWARE Project,
	Flexible Wireless Automation in Real-Time Environments,
	Commission within the 7 EP
	Involved in standardization activities as Member of the International
	Electrotecnical Commission (IEC), Technical Committee SC65C,
	as member of
	Working Group 16, dealing with Wireless Industrial
	communication networks.
	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: <u>http://www.upcnet.es/~pmc16/</u>
Technical role(s) within ArtistDesign	Real-time systems and control systems co-design
Research interests	Real-time and control systems, overload handling, jitter analysis and compensation, control theory.
Role in leading conferences/journals/etc in the area	Program committee member of major real-time and control conferences. Reviewer for the Real-Time Systems Journal.

#### 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

Pau Martí (UPC) Anton Cervin (ULUND)