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

Activity - Progress Report for Year 1

Resource Aware Operating Systems

Clusters:

Operating Systems and Networks

Hardware Platforms and MPSoC Design

SW Synthesis, Code Generation and Timing Analysis

Activity Leader:

Prof. Giorgio Buttazzo (Scuola Superiore S. Anna)
http://feanor.sssup.it/~giorgio/

Policy Objective (abstract)

The objective of this activity is to show how current operating systems can be designed to support emerging real-time applications that exhibit a high degree of complexity and operate in highly dynamic environments where resource demands can change unpredictably. Adaptive resource management mechanisms will be investigated both in uniprocessor and multicore architectures. The impact on operating system standards (like RT-POSIX and OSEK) will also be taken into account.

Versions

number	comment	date
1.0	First version delivered to the reviewers	December 19th 2008

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1. Overview of the Activity

1.1 ArtistDesign Participants and Roles

Cluster Leader: Giorgio Buttazzo – Scuola Superiore S. Anna (Italy)
Role: Activity coordinator, kernel maintenance, development of robotic applications.

Team Leader: Luis Almeida – University of Aveiro (Portugal)
Role: networking platform, development of distributed applications.

Team Leader: Gerhard Fohler – University of Kaiserslauten (Germany)
Role: video streaming applications, scheduling.

Team Leader: Michael Gonzalez Harbour – University of Cantabria (Spain)
Role: definition of the POSIX operating system interface.

Team Leader: Alan Burns – University of York (UK)
Role: feasibility analysis of fixed priority real-time systems.

Team Leader: Eduardo Tovar – Polytechnic Institute of Porto (Portugal)
Role: distributed applications and QoS over heterogeneous networks.

1.2 Affiliated Participants and Roles

Team Leader: Tullio Facchinetti – University of Pavia (Italy)
Role: embedded real-time systems and robotics applications.

Team Leader: Paolo Gai – Evidence s.r.l. (Italy)
Role: real-time kernels and operating systems standards.

Team Leader: Hermann Haertig – Universtity of Dresden (Germany)
Role: microkernel architectures and virtualization techniques

Team Leader: Liesbeth Steffens – NXP (The Netherlands)
Role: real-time kernels for media processing applications.

Team Leader: Pau Marti – Universitat Politècnica de Catalunya (Italy)
Role: control applications and schedulability of event-driven control systems.

Team Leader: Alejandro Alonso – Technical University of Madrid (Spain)
Role: QoS resource management, high integrity systems

Team Leader: Marisol García Valls – Carlos III University of Madrid (Spain)
Role: memory management in real-time Java middleware.

Team Leader: Alfons Crespo –Technical University of Valencia (Spain)
Role: real-time memory management, virtualization of real-time kernels

Team Leader: Salvatore Scafidi – Windriver (Italy)
Role: real-time operating systems

Team Leader: Stylianos Mamagkakis – IMEC Leuven (Switzerland)
Role: Energy-aware scheduling and memory management for dynamic applications

Team Leader: Antonio Bersani – Microchip Technology (Italy)
Role: Hardware components and I/O devices for real-time applications

1.3 Starting Date, and Expected Ending Date

Starting date: January 1st, 2008

Ending date. December 31st, 2010.

1.4 Policy Objective

The main objective of this activity is to investigate how current real-time operating systems have to be extended or modified to support emerging real-time embedded systems characterized by a high degree of complexity, highly variable resource requirements and parallel processing such as multicores. Most embedded systems are often characterized by scarce resources, in terms of processing power, memory, space, weight, energy, and cost. Hence, another objective is to investigate kernel mechanisms that can efficiently manage the available resources, taking multiple constraints into account, whilst guaranteeing isolation properties. Also, to support dynamic applications with variable resource requirements or to cope with unpredictable resource availability, feedback control techniques for resource management at the operating system and application level will be investigated. The impact on operating system standards (like RT-POSIX and OSEK) will also be taken into account. In fact, developing real-time applications and components using an interface compliant to a standard will promote portability to other compliant platforms and will challenge the current standard to be extended to better meet the needs of advanced applications with flexible resource requirements. We realize though that in specific application domains, significant performance advantages can be realized by optimizing software across layers, for example exploiting specific behaviour of a medium access control protocol. This is often the case in operating systems for sensor network platforms such as TinyOS or NanoRK. Such cross-layer design does not necessary contradicts operating system standards, but they do require other interfaces.

1.5 Background

Although there is a large variety of real-time operating systems (RTOSs) varying in sizes, level of provided services, and efficiency, there are some common elements that can be found in most of them:

- An RTOS usually provides support for concurrent programming via processes or threads or both. Processes usually provide protection through separate address spaces, while threads can cooperate more easily by sharing the same address space, but with no protection.
- Real-time scheduling services are provided because this is one of the keys to obtaining a predictable timing behaviour. Most current RTOS's provide the notion of a scheduling priority, usually fixed, as for the moment there are few systems providing deadline-driven or other dynamic-priority scheduling.
- Although some RTOS designed for high-integrity applications use non preemptive scheduling, most support preemption because it leads to smaller latencies and a higher degree of utilization of the resources.
- The OS has to support predictable synchronization mechanisms, both for events or signal and wait services, as well as for mutual exclusion. In the later case some way of preventing priority inversion is required because otherwise very improbable but also very long delays may occur. The common mechanism used to prevent priority inversion is the use of some priority inheritance protocol in the mutual exclusion synchronization services. Priority inversions must also be avoided in the internal kernel implementation; among other things this requires the use of priority queues instead of regular FIFO

queues in those OS services where processes or threads may be queued waiting for some resource.

- The OS has to provide time management services with sufficient precision and resolution to make it possible for the application to meet its timing requirements.
- OS behaviour should be predictable, and so metrics of the response time bounds of the services that are used in real-time loops should be clearly given by the RTOS manufacturer or obtained by the application developer. These metrics include the interrupt latency (i.e., time from interrupt to task run), the worst case execution time of the system calls used in real-time loops, and the maximum time during which interrupts are masked or disabled by the OS and by any driver.

An RTOS is generally chosen not only for its real-time characteristics, but also for the middleware that is integrated in the RTOS, such as file system, communication stack, for its portability to different platforms (i.e., the board support packages that are provided), and for the associated cross-development environment.
A commercial RTOS is usually marketed as the run-time component of an embedded development platform, which also includes a comprehensive suite of (cross-) development tools and utilities and a range of communications options for the target connection to the host, in an Integrated Development Environment (IDE). Moreover, the vendor generally provides development support. For each successful open source RTOS there is also at least one commercial distributor that provides development tools and development support. For many embedded-systems companies, the availability of development tools and support is a major requirement for choosing a particular RTOS. The quality of the overall package deal, including service and pricing strategy is often decisive in choosing a particular RTOS.

Development Tools
In addition to the general programming tools, such as (graphical) editors, compilers, source code browsers, high-level debuggers, and version control systems there are a number of tools specifically aiming cross development, and run time analysis. Advanced tools in this domain not only address development and analysis of the own application code, but also third-party code and the integration with the OS. Memory analyzers show memory usage and reveal memory leaks before they cause a system failure. Performance profilers reveal code performance bottlenecks and show where a CPU is spending its cycles, providing a detailed function-by-function analysis. Real-time monitors allow the programmer to view any set of variables, while the program is running. Execution tracers display the function calls and function calling parameters of a running program, as well as return values and execution time. Event analyzers allow the programmer to view and track application events in a graphical viewer with stretchable time scale, showing context switches, semaphores, message queues, signals, tasks, timers, etc. Simulators enable application development to begin before hardware becomes available, allowing a large portion of software testing to occur early in the development cycle.

Schedulability Analysis Tools
There are different commercially available schedulability analysis tools: TimeWiz from Time Sys Corporation, and RapidRMA from TriPacific are based on Rate Monotonic Analysis (RMA, a modelling and analysis approach for fixed priority systems) [Kle93]. SymTA/S - Symbolic Timing Analysis for Systems - is a system-level performance and timing analysis approach based on formal scheduling analysis techniques and symbolic simulation. These tools allow designers to test software models against various design scenarios and evaluate how different implementations might optimize the performance of their systems, and isolate and identify potential scheduling bottlenecks of both soft and hard real-time systems. There are also WCET analyzer tools: aiT, from AbsInt takes the pipelining and caching of modern processors into

account when determining worst-case execution times; RapiTime is an analysis tool that determines worst-case execution times (WCET) for software components running on advanced microprocessors using path analysis techniques and statistical methods.
These tools benefit from the great success in real-time scheduling theory; results that were developed in the 1970:ies and 1980:ies, and are now well-established and part of the undergraduate curriculum world-wide. Considering the rapid increase in the use of multicores, it is desirable to also develop such tools for multicores. Unfortunately, concerning these, the scheduling theory in real-time scheduling is significantly lagging behind the single processing theory and significant basic research problems are still unsolved. There is however some fair expectation that schedulability analysis tools for multicores will be designed successfully in the near future and have large impact in some of the issues related to this activity. Tiny operating systems such as TinyOS or Nano-RK are usually used in distributed ubiquitous systems. Tools for schedulability analysis of applications for such assemblies exist such as Avrora (from UCLA) or Tossim (from Berkeley). Although trying to engage a holistic view of the system (taking into account application tasks, OS and network specificities), there are still limitations on their use. Some partners in this activity have been addressing efforts related with making such tools available and practical.

1.6 Technical Description: Joint Research

The technical achievements expected will enable the development of resource efficient embedded systems for a broad scope of application domains, e.g., consumer electronics, automotive systems, industrial automation and sensor networks. These achievements, however, will require overcoming technical difficulties inherent to certain conflicting goals. For example, real-time techniques need a priori knowledge for providing guarantees while adaptive mechanisms will allow such knowledge to vary on-line. This variation will also complicate achieving safety and possibly other properties that are also commonly based on a priori knowledge. Moreover, resource usage imposes, many times, couplings and trade-offs between different tasks in the system, thus managing resources while considering such couplings to avoid undesired blocking and interference is another problem that will need to be overcome. In order to solve these difficulties, we will make use of cutting-edge methodologies on which the involved groups are currently working on, such as flexible scheduling, flexible modes, dynamic QoS management and dynamic reconfiguration.

Multicore embedded real-time systems
Next generation RTOS must allow optimal off-line partitioning of the application source code on the different CPUs available on multicore heterogeneous systems, as well as on-line strategies for the run-time migration with the objective of guaranteeing optimal usage of the CPUs available, with real-time response as well as minimization of power consumption.

Component-based operating systems
To optimize the use of resources and increase software portability on different platforms, it is highly desirable to compose the operating system using the functions strictly necessary for the application. To achieve this goal, it is crucial to design the operating system to be modular, so that each component can be independently developed from the others and can be replaced without changing the application.

Microkernels and virtualization
Microkernel-based systems are based on the idea that the highest hardware-level privileges should be constrained to the smallest possible inner core of systems, the microkernel. All the other functions are provided by user-level servers. Microkernels supporting legacy operating systems and their applications are sometime also called hypervisors. Such systems provide interesting benefits and challenges. One of important, if not *the* most important benefit lies in

the additional of security that such systems can provide: a successful penetrator into a legacy operating system compartment in a microkernel-based systems cannot harm other, highly critical parts of the system. This can be achieved if microkernels (such as L4/Fiasco) are designed to provide temporal and spatial separation and temporal, hard or statistical temporal guarantees. Among the challenges for such systems is the close interaction of inter-process communication with scheduling which requires a very carefully designed interface. Such questions will be studied in the project.

Hypervisor for embedded systems
The main open issues related to the hypervisor design are:
- Scheduling policies for domains
- Shared resources management
- Driver support
- Adaptation of new OS to work with a virtualised platform
- Deployment of multiple operating systems on multicore processor platform
- Security issues

1.7 Problem Tackled in Year 1

In the first year, we mainly focused on the following issues:

- **Pisa**: Partitioning a real-time application in a multi-core architecture, with the objective of providing the resource reservation abstraction to achieve temporal protection and to allocate a fraction of the available resources to a given application. Unfortunately, extending the resource reservation paradigm to multicore architectures is not trivial, since resource allocation must be considered together with the problems of exploiting the intrinsic parallelism of certain applications.
- **Pisa**: Another issue we started to investigate in this first year is the evaluation of the interactions of cache memories with scheduling. In particular, preemptive algorithms tend to destroy the cache content of the preempted activity, so increasing the number of cache misses, causing an increase of task computation times. To better evaluate such dependencies we decided to perform a set of simulation experiments aimed at measuring such effects in different scenarios and working conditions.
- **Pavia**: We started investigating the possibility of executing different operating systems on a single multicore platform, by assigning a different core to each operating system, as a special kind of virtualization technique that does not rely on lower-layer components. The short-term goal is to run a real-time operating system along with a general-purpose one in a completely transparent fashion, while the subsequent research will address the cross effects between the operating systems due to shared resources, like memory, bus, peripherals and cache.
- **Pavia**: Specific work on embedded and robotics applications has been started. In this domain the research directions focuses on the development of applications based on small micro-controllers to assess the benefits of real-time computing for the predictability and the overall performance and the application.
- **Catalonia**: We also started to investigate the schedulability analysis of a specific type of control applications named event-driven control applications. The importance of these type of controllers is that they can provide the same control performance than standard periodic controllers while minimizing resource utilization.

2. Summary of Activity Progress

2.1 Technical Achievements

Modeling and analysis of control-driven tasks (Scuola Superiore Sant'Anna and Technical University of Catalonia)

The standard design of control systems is based on the periodic sampling. Every period the data is read from the input, the control law is computed, and the output is written to the actuators. However the periodicity of the sampling instants is a constraint that arises from the ease of implementation and it is not strictly necessary in the control system. In this work we focus on an execution model that samples the input "when needed". This model saves a considerable amount of computational resources. We investigate the schedulability analysis for a set of control-driven tasks using both Fixed Priority (FP) and Earliest Deadline First (EDF). A join publication can be found at
http://www.upcnet.es/~pmc16/rtss08.pdf

MPSoC runtime resource management (IMEC. affiliated to York)

Imec evaluated the S.Ha.R.K kernel (Soft Hard Real-Time Kernel by the RETIS lab of the Scuola Superiore Sant'Anna, Italy). It would be used as a modular real time operating system in the OptiMMA IWT project for MPSoC runtime resource management. Complementary approaches are currently explored, which support management of heterogeneous MPSoC platforms.

Implementation of a flexible scheduling framework (Cantabria, York, Pisa, Valencia, and several academic and industrial partners)

Implementation efforts have been carried out on the integration of new resources in a flexible scheduling framework called FRSH that is capable of handling multiple concurrent activities with different criticality and timing in the same system, integrating the management of different kinds of resources such as processors, networks, memory, energy, and shared objects with time protection. New communication networks have been added: CAN bus, as a representative of fieldbusses, Wifi, as a representative of wireless networks, wired Ethernet, and switched Ethernet using industrial switches. An implementation to manage disk bandwidth is underway. Implementations on FPGAs and multiprocessor systems are also underway. In addition, the effects of power management are being introduced in one of the implementations.

The framework has been designed to be implementable on different platforms and work has been carried out to implement the framework on POSIX RTOSs (Partikle/RT-Linux, MaRTE OS), a commercial RTOS used in telecommunications (OSE), and in main-stream Linux kernels. An analysis module developed in the University of York was integrated in the framework to provide advanced schedulability analysis capabilities.

Erika Support for the EasyBee radio transceiver (Scuola Superiore Sant'Anna, Pavia, Evidence)

A driver for the EasyBee radio transceiver has been developed under the Erika real-time kernel and the Flex board. This is a transceiver operating on the frequency of 2400MHz and providing some hardware facilities, which can be exploited to develop different communications

protocols, such as the IEEE802.15.4. The interface between the kernel and the driver has been realized through and Hardware Abstraction Layer (HAL), which makes the interface independent from the driver. An application implementing a simple MAC layer protocol has been developed to test the driver. The application consists of two nodes that exchange messages periodically. A CSMA/CA algorithm is used to manage the channel access to the nodes.

Application note: http://www.evidence.eu.com/content/view/278/266/

Transceiver EasyBee: http://www.rfsolutions.co.uk/acatalog/EasyBee_Zigbee_Module.html

Operating system support for the Real-Time Specification for Java (University of York, University of Cantabria)

York has been tackling issues relating to the operating system support needed by advanced users of the Real-Time Specification for Java. In particularly, two issues have been addressed. The first is how to handle systems that contain a large number of asynchronous event, each of which many release one of more handlers, each of which has specific timing requirements. The second is the issue of how to measure blocking time. During our research we build on the work of MaRTE OS produced at the University of Cantabria. In addition to this we have been investigating the role of reflection for efficient application-tailored resourced management within an RTOS.

Real-time MPEG video decoding on multicore platforms (TUKL**)**

TUKL started work on strategies for distributing functional parts of video decoding on multicore platforms with particular focus on synchronization issues. Based on previous work, including in ARTIST2, on quality aware real-time MPEG decoding in resource constrained systems, TUKL has been studying issues related to multicore platforms. This includeds partitioning of decoding functions based on the source code to provide timely decoding, and focuses on synchronization issues.

2.2 Individual Publications Resulting from these Achievements

Scuola Superiore Sant'Anna of Pisa

- Giorgio Buttazzo, "Artificial Consciousness: Hazardous Questions (and Answers)", Journal of Artificial Intelligence in Medicine, Elsevier, to appear.
- Enrico Bini, Marco Di Natale, and Giorgio Buttazzo, "Sensitivity Analysis for Fixed-Priority Real-Time Systems", Real-Time Systems, Vol. 39, No. 1-3, pp. 5-30, August 2008.
- Yifan Wu, Enrico Bini, and Giorgio Buttazzo, "A Framework for Designing Embedded Real-Time Controllers", Proceedings of the 14th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA 2008), Kaohsiung, Taiwan, August 25-27, 2008.
- Marko Bertogna, Michele Cirinei, Giuseppe Lipari, "Schedulability analysis of global scheduling algorithms on multiprocessor platforms", accepted for publication on IEEE Transactions on Parallel and Distributed Systems.
- Luigi Palopoli, Tommaso Cucinotta, Luca Marzario, Giuseppe Lipari, "AQUOSA – Adaptive Quality of Service Architecture", accepted for publication on Software: Practice and Experience.

University of York

- A. Patil and N. Audsley (2008), Adaptive Framework for Efficient Resource Management in RTOS, Proc. APRES, pp12--15.
- M. Kim and A.J Wellings (2008), An efficient and predictable implementation of asynchronous event handling in the RTSJ, JTRES '08: Proceedings of the 6th international workshop on Java technologies for real-time and embedded systems, pp48--57.
- O. M. dos Santos and A.J Wellings (2008), Blocking time monitoring in the Real-Time Specification for Java, JTRES '08: Proceedings of the 6th international workshop on Java technologies for real-time and embedded systems, pp135--143.
- O. M. dos Santos and A.J. Wellings (2008), Run Time Detection of Blocking Time Violations in Real-Time Systems, 14th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications, pp347-356.

University of Pavia (affiliated to Pisa)

- Luca Capisani, Tullio Facchinetti, Antonella Ferrara, Alessandro Martinelli, "Environment Modelling for the Robust Motion Planning and Control of Planar Rigid Robot Manipulators", in Proceedings of the 13th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), Hamburg, Germany, September, 2008.
- Tullio Facchinetti, Gianluca Franchino, Giorgio Buttazzo, "A Distributed Coordination Protocol for the Connectivity Maintenance in a Network of Mobile Units", International Conference on Advances in Mesh Networks (MESH), Cap Esterel, France, August, 2008.

Technical University of Valencia (affiliated to Cantabria)

- S. Peiro, M. Masmano, I. Ripoll, and A. Crespo, “To develop a platform for the evaluation of PaRTiKle LPC, port to the LPC2000” Tenth Real-Time Linux Workshop. October 29-31. 2008.
- V. Brocal, M. Masmano, I. Ripoll and A. Crespo, “Supporting the FRSH real-time framework on top of PaRTiKle”. Tenth Real-Time Linux Workshop, October 29-31, 2008.
- Miguel Masmano, Ismael Ripoll, Patricia Balbastre, Alfons Crespo. “A constant-time dynamic storage allocator for real-time systems”, Real-Time Systems. Vol. 40, No. 2, pp 149-179, November 2008.
- A. Marchand, P. Balbastre, I. Ripoll, and A. Crespo, “Providing Memory QoS Guarantees for Real-Time Applications”, Proc. of the IEEE International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA 2008) Kaohsiung, Taiwan, August 25-27, 2008.

2.3 Interaction and Building Excellence between Partners

Cantabria, Valencia and Pisa have collaborated towards editing a special issue of the EURASIP Journal on Embedded Systems on “Operating System Support for Embedded Real-Time Applications”. The special issue had six papers accepted, some of which are closely related to adaptive resource management in real-time systems.

The Scuola Superiore Sant’Anna of Pisa, the University of Pavia and the University of Catalonia started a collaboration with the cluster on Control for Embedded Systems to integrate real-time and control theory for implementing adaptive systems. New jitter/delay

reduction methods have been proposed and evaluated to improve the performance of real-time control systems. External collaborations on this topic were also established with the University of Illinois at Urbana Champaign (Prof. Lui Sha, Prof. Tarek Abdelzaher, and Prof. Marco Caccamo), the University of Virginia (Prof. John Stankovic), the University of North Carolina at Chapel Hill (Prof. Sanjoy Baruah), and the University of Halmstad, Sweden (Prof. Bertil Svensson).

The Scuola Superiore Sant'Anna of Pisa also started a collaboration with the cluster on Execution Platforms (and in particular with Bologna, Saarland, Dortmund and ETH Zurich) for evaluating the effects of scheduling algorithms on cache memories, with the purpose of reducing variability in the task worst-case execution times. The idea is that preemptive scheduling destroys cache data and prefetch queues, so a number of experiments were discussed to verify how scheduling affects execution times.

Scuola Superiore Sant'Anna of Pisa, University of Kaiserslautern, and University of Lund, started investigating how to achieve adaptive resource reservations in multi-core architectures, providing the right level of abstractions at different programming layers. Both operating system mechanisms and feedback scheduling algorithms are being considered to approach the problem.

2.4 Joint Publications Resulting from these Achievements

- Manel Velasco, Pau Martí and Enrico Bini, "Control-driven Tasks: Modeling and Analysis", Proceedings of the 29th IEEE Real-Time Systems Symposium (RTSS08), Barcelona, Spain, December, 2008.
- Tullio Facchinetti, Gianluca Franchino, Giorgio Buttazzo, "A Distributed Coordination Protocol for the Connectivity Maintenance in a Network of Mobile Units", International Conference on Advances in Mesh Networks (MESH), Cap Esterel, France, August, 2008.
- Francesco Benzi, Tullio Facchinetti, Thomas Nolte, Luis Almeida, "Towards the Powerline Alternative in Automotive Applications", Proceedings of the 7th IEEE International Workshop on Factory Communication Systems (WFCS) - WiP, Dresden, Germany, May 20-23, 2008.
- Gianluca Franchino, Tullio Facchinetti, and Giorgio Buttazzo, "Time Properties of the Bust Protocol Under the NPA Budget Allocation Scheme", Proceedings of the Conference on Design, Automation and Test in Europe (DATE), Munich, Germany, March 10-14, 2008.
- Gianluca Franchino, Giorgio Buttazzo, and Tullio Facchinetti, "Properties of BuST and Timed Token Protocols in Managing Hard Real-Time Traffic", Proceedings of the 13th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2008), Hamburg, Germany, September 15-18, 2008.
- Luigi Palopoli, Luca Abeni, Tommaso Cucinotta, Giuseppe Lipari, Sanjoy Baruah, "Weighted Feedback Reclaiming for Multimedia Applications", 6th IEEE Workshop on Embedded Systems for Real-Time Multimedia, October 2008.
- Luca Abeni, Claudio Scordino, Giuseppe Lipari, "Serving non real-time tasks in a reservation environment", Real-Time Linux Workshop, 2008.
- Rodrigo Santos, Giuseppe Lipari, Enrico Bini, "Efficient on-line schedulability test for feedback scheduling of soft real-time tasks under fixed-priority", IEEE Real-Time and Embedded Technology and Applications Symposium, Saint Louis USA (2008) (pdf)
- Antonio Mancina, Jorrit Herder, Ben Gras, Andrew Tanenbaum, Giuseppe Lipari, "Enhancing a Dependable Multiserver Operating System with Temporal Protection via

Resource Reservations", 16th International Conference on Real-Time and Network Systems, Rennes, France, October 2008 (pdf)

- Francesco Benzi, Tullio Facchinetti, Thomas Nolte, Luis Almeida, "Towards the Powerline Alternative in Automotive Applications", Proceedings of the 7th IEEE International Workshop on Factory Communication Systems (WFCS) - WiP, Dresden, Germany, May 20-23, 2008.
- Rodrigo Santos, Giuseppe Lipari, Jorge Santos, "Improving the schedulability of soft real-time open dynamic systems: The inheritor is actually a debtor", Journal of Systems and Software, vol. 81, pagg. 1093 – 1104, 2008.
- P. Pagano, C. Nastasi, Y. Liang, The multivision problem for Wireless Sensor Networks: a discussion about Node and Network architecture, 4th IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS), Jun. 2008. Invited talk.
- Alfons Crespo, Ismael Ripoll, Michael González-Harbour, and Giuseppe Lipari, "Operating System Support for Embedded Real-Time Applications". EURASIP Journal on Embedded Systems, Volume 2008 (2008), Article ID 502768,, February, 2008, pp. 1,2.
- M. Masmano, I. Ripoll, J. Real, A. Crespo, A. J. Wellings (2008) Implementation of a constant-time dynamic storage allocator, Software: Practice and Experience, Vol 38, No 10, pp995-1026.

2.5 Keynotes, Workshops, Tutorials

Workshop: Fourth International Workshop on Operating Systems Platforms for Embedded Real-Time Applications (OSPERT 2008)
Prague, Czech Republic – July 1st, 2008

Objectives: This workshop was intended as a forum for researchers and practitioners of RTOS to discuss the recent advances in RTOS technology and the challenges that lie ahead. The workshop consisted of submitted papers as well as invited presentations about academic state-of-the-art and industrial state-of-practice within the area of real-time operating systems architectures and services.

Organizers:

- Jim Anderson, University of North Carolina, Chapel Hill, USA
- Gerhard Fohler, University of Kaiserslautern, Germany

URL: http://www.cs.unc.edu/~anderson/meetings/ospert08/OSPERT.html

Workshop: Fieldbuses for Automotive and the Powerline Alternative
Pavia, Italy - January 24, 2008

Organizers:

- Tullio Facchinetti, University of Pavia, Italy
- Francesco Benzi, University of Pavia, Italy

Objectives: The workshop focused on the aspects, both from the physical and communication protocol side, about the use of powerline for the communication in the automotive domain. The main technologies for automotive communication have been presented (LIN, CAN, FlexRay) to compare a possible solution based on powerline. The discussion led to the guidelines to

conduct further research and experiment on the topic, mainly in the direction of evaluating the timing characteristics of available powerline components.

Workshop: International Meeting on Powerline for - but not limited to - Automotive
Pavia, Italy – November 4, 2008

Organizers:

- Tullio Facchinetti, University of Pavia, Italy
- Francesco Benzi, University of Pavia, Italy

Objectives: The workshop focused on establishing possible collaborations on the field of the communication in the automotive domain. However, the target domain has not been limited automotive, but also included the space domain and other vehicular domains. The discussion raised a number of interesting research directions, that will involve expertises from different fields like electrical and electronic engineering, real-time networking and computing, artifical intellingence. The event has been endorsed by the IEEE EMC-S IT Chapter.

URL: http://robot.unipv.it/component/content/article/64

Workshop: Operating Systems and Networks
Pisa, Italy – October 2-3, 2008

Objectives: The purpose of the workshop was to refine the research objectives of the cluster on Operating Systems and Networks and coordinate the collaboration among the different groups. Discussed topics included: architecture effects on worst-case execution times, taxonomy of resources, real-time networks, and real-time and control issues.

Organizers:

- Giorgio Buttazzo - Scuola Superiore Sant'Anna, Italy
- Alan Burns – University of York, UK
- Luis Almeida, Univ. of Aveiro, Portugal

Tutorial: Real-time Kernels for Microcontrollers: Theory and Practice
Pisa, Italy – June 23-25, 2008

Organizers:

- Giorgio Buttazzo - Scuola Superiore Sant'Anna, Italy
- Paolo Gai, Evidence Srl
- Tullio Facchinetti, University of Pavia, Italy
- Ettore Ricciardi – ISTI-CNR, Pisa

Objectives: The course introduced the basic concepts of Real-time Systems targeted to Embedded Systems, which are often implemented using microcontrollers. The course briefly illustrated the theoretical background of real-time scheduling, resource-aware techniques, and wireless communication based upon the IEEE 802.15.4 protocol. A practical implementation of the presented concepts has been shown by describing the Erika Enterprise kernel, which is an extremely low footprint kernel featuring state-of-the-art real-time technologies targeted to microcontrollers for embedded applications. The course included a set of practical experiences to allow a faster, better and complete understanding of problems related to embedded

applications design. The laboratory activities made use of the FLEX embedded boards, fully integrated with Erika Enterprise, and a set of integrated tools for the automatic code generation and application performance profiling.

URL: http://www.artist-embedded.org/artist/Real-Time-Kernels-for.html

Tutorial: Real-Time Control Systems: Theory and Practice
Pisa, Italy – April 2-18, 2008

Objectives: The objective of the course was to introduce classical control notions applied to real-time computing systems. Topics included Discrete time systems, Exact Real-time simulation, period selection, delayed models, controllability, observability and performance of discrete time controllers, real-time computing of control systems, timing and implementation, control of real-time systems, event-driven systems, scheduling of event driven systems.

Organizers:

- Giorgio Buttazzo - Scuola Superiore Sant'Anna, Italy
- Manel Velasco – University of Catalonia, Spain

Tutorial: A Multi-Processor Architectural Simulator (MPARM)
Pisa, Italy – November 5-6, 2008

Objectives: The objective of the course was to introduce MPARM, a simulator for multi-processor architectures developed at the University of Bologna. Martino Ruggiero, who participated in the development, gave a tutorial in Pisa to explain the MPARM architecture, the available hardware modules, their profiling features, possible power models, how add new modules to MPARM, the software development flow, the application profiling, debugging features, the operating system interface, the communication library, and a few examples.

Organizers:

- Giorgio Buttazzo - Scuola Superiore Sant'Anna, Italy
- Luca Benini – University of Bologna, Italy
- Martino Ruggiero – University of Bologna, Italy

3. Milestones, and Future Evolution

3.1 Problem to be Tackled over the next 12 months (Jan 2009 – Dec 2009)

In the next 12 months the cluster will investigate the follwing issues:

- Schedulability analysis of event-driven control systems (Pisa, Catalonia, Lund).
- Adaptive resource reservation algorithms for multicore platforms (Pisa, TULK, Lund, York, Cantabria).
- Evaluate the effects of scheduling and cache memories on task execution times, with the objective of reducing the variabily of WCET estimations (Pisa, Saarland, Bologna).
- Systematic allocation and synchronization of decoding functions for quality aware real-time MPEG-2 decoding on multicore platforms and develop initial algorithms (TUKL).

3.2 Current and Future Milestones

Year 1:

1. **Model resource reservation on multi-core architectures (Achieved)**. The concept of resource reservation has been extended to multi-core architectures, with the objective of achieving temporal protection among different applications.
2. **Educational kit for embedded control applications (Achieved)**. An educational kit for embedded systems, based on Microchip dsPIC technology, has been developed at the Scuola Superiore Sant'Anna of Pisa, in collaboration with Pavia, Evidence, Embedded Solutions, and Microchip Technology. It consists of a number of modules that can easily be composed depending on specific application purposes. The modules include a set of libraries to simplify the access to the hardware devices (sensors, servomotors, wireless modules) and a number of sample real-time control applications that can be easily replicated by the users.
3. **XtratuM hypervisor (Achieved)**. The XtratuM hypervisor has been developed at the Technical University of Valencia and has substituted the RTLinux distribution to provide full temporal and spatial isolation to real-time partitions and Linux partition. In particular, XtratuM has been ported to Leon2 processors (the processor used by ESA in the space) under a project funded by CNES (France) following the ARINC 653 standard. XtratuM can now be used as a test platform for the techniques proposed in this activity.

Future milestones:

- Extend the XtratuM hypervisor execution platform to multiprocessor systems.
- Provide a set of tools to simplify the development of real-time control applications on the educational kit.
- Analyze the problem of specifying the intrinsic parallelism of real-time applications and provide a method for guaranteeing the timing constraints of the parallel execution flows. Then, investigate how to implement adaptive resource reservation algorithms on multicore architectures.

- Evaluate the effects of scheduling and cache memories on task execution times, with the objective of reducing the variabily of WCET estimations.
- Investigate component-based operating systems to increase software modularity, configuration flexibility and portability on different platforms.

3.3 Main Funding

The basic research on real-time operating systems and advanced scheduling techniques come from the following European projects:

FRESCOR - Framework for Real-time Embedded Systems based on COntRacts

FRESCOR is a consortium research project funded in part by the European Union's Sixth Framework Programme (FP6/2005/IST/5-034026). The following ArtistDesign partners are involved: University of Cantabria, University of York, Scuola Superiore Sant'Anna, Technical University of Kairserslautern, Technical University of Valencia. The main objective of the project 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. The approach to achieve this main objective is to integrate advanced flexible scheduling techniques directly into an embedded systems design methodology, covering all the levels involved in the implementation, from the OS primitives, through the middleware, up to the application level. This will be achieved by creating a contract model that specifies which are the application requirements with respect to the flexible use of the processing resources in the system, and also what are the resources that must be guaranteed if the component is to be installed into the system, and how the system can distribute any spare capacity that it has, to achieve the highest usage of the available resources.

http://www.frescor.org/

ACTORS - Adaptivity and Control of Resources in Embedded Systems

ACTORS is a three-year research project within the European Commission's 7th Framework Programme involving the following ArtistDesign partners: Lund University, Scuola Superiore Sant'Anna, and Technical University of Kairserslautern. It addresses design of resource-constrained software-intensive embedded systems with high requirements on adaptivity and efficiency. Three techniques are combined: virtualization, feedback control, and data-flow programming models. Virtualization techniques such as reservation-based scheduling provide spatial and temporal separation of concerns and enforce dependability and predictability. Reservations can be composed, are easier to develop and test, and provide security support. Using feedback-based resource management, the resource allocation is based on a comparison of the actual resource utilization of, e.g., a set of activities or tasks, with the desired resource utilization. The difference is used for deciding how the resources should be dynamically allocated. Feedback control makes it possible to deal with uncertainties and variations in a controlled way and provides adaptivity to on-line changes in objectives, external conditions and use cases. By combining feedback control with resource reservations it is possible to handle incorrect reservations, reclaim and redistribute unused resources, and adjust to dynamic changes in resource requirements.

http://www.actors-project.eu/index.php/

PREDATOR - Design for predictability and efficiency

PREDATOR is a three-year focused-research project within the European Commission's 7th Framework Programme on Research, Technological Development and Demonstration. The following ArtistDesign partners are involved: Saarland University, Scuola Superiore Sant'Anna, Technische Universität Dortmund, and University of Bologna. The project is concerned with embedded systems that are characterised by efficiency requirements on the one hand and critical constraints on the other. This combination of requirements typically occurs in application domains such as automotive, aeronautics, multi-media and industrial automation.

http://www.predator-project.eu/

THREAD Spanish project

The following ArtistDesign partners are involved: Technical University of Madrid, University of Cantabria, and Technical University of Valencia.

http://polaris.dit.upm.es/%7Estr/proyectos/thread/

4. Internal Reviewers for this Deliverable

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Marco Caccamo (University of Illinois at Urbana Champaign)