IST-004527 ARTIST2
Network of Excellence
on Embedded Systems Design

Activity Progress Report for Year 3

JPIA-Platform
A Common Infrastructure for Adaptive Real-time Systems

Clusters:

Adaptive Real-Time

Activity Leader:

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Policy Objective (abstract)

The objective of this activity is to show how current operating systems and network protocols have to be extended to support emerging real-time applications that exhibit a high degree of complexity and operate in dynamic environments.

The impact on operating system standards (like RT-POSIX and OSEK) as well as network protocols will also be taken into account.

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1. Overview of the Activity

1.1 ARTIST 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 – Technical 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: Ivo De Lotto – University of Pavia (Italy)
Role: kernel maintenance.

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

Team Leader: Lucia Lo Bello – University of Catania (Italy)
Role: Distributed real-time applications.

Team Leader: Pau Marti – Universitat Politècnica de Catalunya (Italy)
Role: control applications.

1.3 Starting Date, and Expected Ending Date

Starting date: September 1st, 2004

Ending date. August 2008

1.4 Baseline

At the beginning of the activity, most of the partners were not familiar with the Shark operating system and could not exploit the potentiality of the kernel in developing software applications using advanced real-time mechanisms, such as dynamic scheduling, proirity inheritance, resource reservation, aperiodic servers, and overload management algorithms. Moreover, they could not practically evaluate the impact of a specific kernel mechanism on the performance of a dynamic real-time application, simply because the existing kernels usually provide fixed policies that cannot be easily replaced or modified by the user.

However, each partner had a solid theoretical expertize in real-time systems and also some practical experience in one or more application domains. These conditions were exploited to evaluate the suitability of several kernel mechanisms to support the development of different

types of real-time applications, including monitoring systems, robotics, control systems, and multimedia processing.

In particular, each team working in this activity gave a complementary contribution to define a common infrastructure for the development of advanced real-time systems:

- Scuola Superiore S. Anna, together with its affiliates University of Pavia and Evidence, has a strong expertize in kernel development, so it ensured the proper support to the other teams for maintaining the Shark kernel and teaching how to use it.
- University of Aveiro, Polytechnic Institute of Porto and University of Catania (affiliated to Pisa) have a strong expertize in real-time networks, which they used to evaluate the impact of kernel mechanisms on distributed real-time applications.
- Mälardalen University (now replaced by Technical University of Kaiserslauten) had already worked on video streaming and multimedia applications, therefore it committed itself to test the kernel on media processing.
- Universitat Politècnica de Catalunya, expert in control systems, gave the availability for testing the kernel on critical control applications.
- University of Cantabria and University of York, actively involved in standards for operating systems interfaces, gave support for implementing a POSIX interface.
- University of York, expert in feasibility analysis of fixed priority systems, gave support for implementing and analyzing new scheduling schemes.
- UP Madrid and its affiliate Univ. Carlos III of Madrid, expert in quality of service management, were the ideal candidates for evaluating the impact of adaptive kernel strategies in multimedia systems.

1.5 Problem Tackled in Year 3

The objective of this activity in the third year was to use the platform for experimenting RTOS mechanisms in control and distributed systems. Each partner selected a specific application with the aim of evaluating the impact of kernel policies on system performance.

A control application has been developed by the Scuola Superiore Sant'Anna, in collaboration with the University of Pavia (for sensors and actuators interfacing), Evidence (for kernel support), and Lund (for controller implementation). A two-degree of freedom device has been built using two servomotors and a camera has been used to track the position and velocity of a ball moving on the plate. An inverted pendulum has been developed by University of Catalonia (affiliated to Pisa). Shark was used to perform sensory acquisition, actuation, control and to test overload management strategies. Mobile robots have been controlled by Shark at the University of Aveiro.

A number of multitask real-time applications have been developed at the Scuola Superiore Sant'Anna to test the behavior of real-time systems under overload conditions. *Resource Reservations* and *Elastic Scheduling* techniques have been evaluated to cope with transient and permanent overload conditions. *Resource Reservations* techniques basically isolate the temporal behavior of a task (or subset of tasks) protecting the rest of the systems from potential overruns. On the other hand, *Elastic Scheduling* provides an effective solution to cope with permanent overload conditions. According to this method, task utilizations are treated as flexible springs that can be compressed (by enlarging periods) to reduce the load up to a desired value. Such novel techniques (not yet available in commercial operating systems) have

been implemented into Shark as basic scheduling modules to be tested and evaluated in actual control applications.

Feedback scheduling mechanisms have been tested at the Technical University of Catalonia (affiliated to TUKL). These have been developed as basic modifications in the Shark kernel to facilitate the application of existing feedback scheduling results. The group at UPM is continuing the porting of HOLA-QoS on top of SHARK. Up till now, the lower levels (Resource Manager) have been ported and a new version of the quality manager (higher layers) is being devoloped. When it will be ready, the software will run on top of SHARK, so that the negotiation and optimization features of HOLA-QoS can be used in SHARK applications.

University of Aveiro is developing a Shark client for the CiberMouse students design competition. TUKL is using Shark as a platform for video processing applications, in particular adaptive resource management for user quality. Algorithms for stream adaptation have been implemented and evaluated on Shark. Representatives from TUKL participated in training for Shark. TUKL is using the Shark kernel in undergraduate education. Two labs have been involved. In one lab, students develop a scheduling algorithm, which they analyse theoretically and practically as implementation on an operating system, i.e., Shark. In the other lab, students implement a simple video processing algorithm they implement on Shark, learning implementation and overhead issues.

University of Catania (affiliated to Pisa) is implementing Traffic Smoothing Techniques on the Shark OS, to make experiments on distributed real-time systems.

1.6 Comments From Year 2 Review

1.6.1 Reviewers' Comments

No particular comments were raised for this activity.

1.6.2 How These Have Been Addressed

The activity continued according to the planned objectives.

2. Summary of Activity Progress

2.1 Previous Work in Year 1

Initial definition of the operating system and network features. *The SHARK operating system developed at the Scuola Superiore Sant'Anna of Pisa has been identified (for the reasons explained in* Deliverable 2-2 JPIA-a-ART-Y1*) as the most suited kernel for building a common infrastructure to perform advanced experiments on real-time systems.*

2.2 Previous Work in Year 2

The objective of this activity in the second year was to deploy a working platform for experimenting RTOS mechanisms in control and distributed systems. Each partner selected a specific application with the aim of evaluating the impact of kernel policies on system performance. Sample real-time applications included mobile robotics, distributed systems, multimedia processing, and process control systems.

The specific kernel mechanisms that have been considered for evaluation include:

- **Periodic task scheduling algorithms**. Periodic task scheduling is extremely important since most software control systems are implemented through a set of periodic activities performing data sampling, sensory processing, control, action planning, and actuation. Although not strictly necessary, periodic execution simplifies the design of control algorithms and allows using standard control theory to guarantee system stability and performance requirements. When several of such activities execute concurrently in the same processor, however, each task may experience a variable delay and jitter, mainly due to the interference created by the other tasks. If not properly taken into account, delays and jitter may degrade the performance of the system and even jeopardize its stability. Fixed priority schemes and deadline-based algorithms (like EDF), both available into Shark, were evaluated in terms of overhead, complexity, jitter and robustness in handling overload conditions.
- **Aperiodic service mechanisms**. In addition to periodic tasks, most of real-time applications include a number of event-driven activities generated by asynchronous interrupts coming from peripheral devices. If not properly handled, aperiodic activities may create transient overload conditions and introduce unbounded delays in periodic control tasks that could degrade system performance in an unpredictable fashion. Several aperiodic service policies, available into Shark, have been tested and evaluated, including Polling Server, Sporadic Server, Deferrable Server, Total Bandwidth Server and Constant Bandwidth Server.
- **Resource access protocols**. When tasks interact through shared memory buffers, additional blocking times can be introduced in task execution due to the access of mutually exclusive resources. Several solutions have been proposed in the literature to bound the maximum delay caused by resource conflicts (e.g. Non-Preemptive Protocol, Higher Locker Priority, Priority Inheritance Protocol, Priority Ceiling Protocol, Stack Resource Policy, Immediate Priority Ceiling, etc.). All these protocols are available in Shark as a specific resource modules and can be used in combination with different scheduling algorithms. In addition, Shark also includes a non blocking communication mechanism (namely, the Cyclic Asynchronous Buffer), based on memory duplication, which represent an interesting alternative for the communication among periodic tasks with different periods. Testing the effectiveness of such inter-task communication mechanisms was one of the objective of this research activity.

- **Overload management techniques**. Dynamic real-time systems are subject to unpredictable load variations which may cause transient or permanent overload conditions. If the system is not designed to handle such a situations, the system performance may degrade in an unpredictable fashion. Transient overload conditions due to execution overruns can be efficiently handled by *Resource Reservations* techniques, which basically isolate the temporal behavior of a task (or subset of tasks) protecting the rest of the systems from potential overruns. On the other hand, *Elastic Scheduling* provides an effective solution to cope with permanent overload conditions. According to this method, task utilizations are treated as flexible springs that can be compressed (by enlarging periods) to reduce the load up to a desired value. Such novel techniques (not yet available in commercial operating systems), have been implemented into Shark as basic scheduling modules to be tested and evaluated in real-world control applications.

2.3 Current Results

2.3.1 Technical Achievements

Perform extensive testing to identify algorithms and tools to support adaptive RT systems. Participate in the evolution of RTOS standards, by introducing advanced scheduling methods for enhancing the predictability of real-time systems and handle their increased complexity. Provide advanced features in OSEK compliant kernels.

Specific applications developed under Shark are described below:

- **Ball balancing**. This control application has been developed by the Scuola Superiore Sant'Anna, in collaboration with the University of Pavia (for sensors and actuators interfacing), Evidence (for kernel support), and Lund (for controller implementation). A two-degree of freedom device has been built using two servomotors and a camera has been used to track the position and velocity of a ball moving on the plate.
- **Inverted pendulum**. This application has been developed by University of Catalonia (affiliated to Pisa). Shark was used to perform sensory acquisition, actuation, control and to test overload management strategies.
- **Mobile Robots**. This application has been developed by University of Aveiro. An inverted pendulum has been mounted on a robot car, which has been controlled to keep the pole in a vertical position.
- **Overload management techniques**. A number of multitask real-time applications have been developed at the Scuola Superiore Sant'Anna to test the behavior of real-time systems under overload conditions. *Resource Reservations* and *Elastic Scheduling* techniques have been evaluated to cope with transient and permanent overload conditions. *Resource Reservations* techniques basically isolate the temporal behavior of a task (or subset of tasks) protecting the rest of the systems from potential overruns. On the other hand, *Elastic Scheduling* provides an effective solution to cope with permanent overload conditions. According to this method, task utilizations are treated as flexible springs that can be compressed (by enlarging periods) to reduce the load up to a desired value. Such novel techniques (not yet available in commercial operating systems) have been implemented into Shark as basic scheduling modules to be tested and evaluated in actual control applications.
- **Feedback Scheduling in SHaRK: a First Approach**. Research Report ESAII-RR-06-13, Automatic Control Department, Technical university of Catalonia, July 2006 (http://www.upcnet.es/~pmc16/shark06.pdf). This work reports basic modifications done

in the shark kernel to facilitate the application of existing feedback scheduling results. No particular application was implemented. Unofficial modification of the S.Ha.R.K. kernel available for download (http://www.upcnet.es/~pmc16/all.tar). Unofficial Knoppix ISO with S.Ha.R.K. available for download (http://www.upcnet.es/~pmc16/knoppix.iso). Authors: Josep Guardia, Pau Martí, Manel Velasco and Rosa Castañé.

- **Porting of HOLA-QoS**. The group at UPM is continuing the porting of HOLA-QoS on top of SHARK. Up till now, the lower levels (Resource Manager) have been ported and a new version of the quality manager (higher layers) is being devoloped. When it will be ready, the software will run on top of SHARK, so that the negotiation and optimization features of HOLA-QoS can be used in SHARK applications.
- **Cibermouse client**. University of Aveiro is developing a Shark client for the CiberMouse@RTSS2006 students design competition. The code can be found here: http://www.ieeta.pt/~lau/web_ciberRTSS/tools.htm
- **Video processing**. TUKL is using Shark as a platform for video processing applications, in particular adaptive resource management for user quality. Algorithms for stream adaptation have been implemented and evaluated on Shark. Representatives from TUKL participated in training for Shark.
- **Education at TUKL**. TUKL is using the Shark kernel in undergraduate education. Two labs have been involved. In one lab, students develop a scheduling algorithm, which they analyse theoretically and practically as implementation on an operating system, i.e., Shark. In the other lab, students implement a simple video processing algorithm they implement on Shark, learning implementation and overhead issues.
- **Traffic Smoothing Techniques**. University of Catania (affiliated to Pisa) is implementing Traffic Smoothing Techniques on the Shark OS, to make experiments on distributed real-time systems.

2.3.2 Individual Publications Resulting from these Achievements

1. Enrico Bini, Marco Di Natale, and Giorgio Buttazzo, "Sensitivity Analysis for Fixed-Priority Real-Time Systems", Real-Time Systems, to appear.
2. Giorgio Buttazzo and Enrico Bini, "Optimal Dimensioning of a Constant Bandwidth Server", IEEE Proc. of the 27th Real-Time Systems Symposium (RTSS 2006), Rio de Janeiro, Brasil, Dec. 2006.
3. Giorgio Buttazzo, "Why real-time computing?", 50th Int. Congress of ANIPLA on Methodologies for Emerging Technologies in Automation (ANIPLA 2006), Rome, Nov. 2006.
4. Giorgio Buttazzo, "Real-Time Scheduling and Resource Management", in The Handbook of Real-Time and Embedded Systems, Edited by Joseph Leung, Insup Lee, and Sang Son, CRC Press, 2006.
5. P. Basanta-Val, M. García Valls, I. Estévez Ayres, and Carlos Delgado-Kloos. Extended Portal: Violating the assignment rule and enforcing the single parent rule. 4th International Workshop on Java Technologies for Real-Time and Embedded Systems (JTRES 06). Accepted for publication (ACM Digital Library). Paris, France, October 11-13th, 2006.
6. P. Breuer and M. García Valls. Raiding the Noosphere: the open development of networked RAID support for the Linux Kernel Software: Practice and Experience. ISBN: 0038-0644. Vol. 36, no. 4, pp. 365-395. Jonh Wiley & Sons, Ltd. April 2006.

7. A Burns and A. J. Wellings, “Concurrent and Real-Time Programming in Ada”. Cambridge University Press. July 2007.

8. A.J. Wellings and A. Burns. “Programming Execution-Time Servers and Supporting EDF Scheduling in Ada 2005”. Handbook of Real-Time and Embedded Systems, Chapman and Hall/CRC, Editor Insup Lee, Joseph Y-T. Leug and Sang H. Son. pp. 13-1 -13-20. July 2007.

9. A.J. Wellings and A. Burns. “Real-Time Java”. Handbook of Real-Time and Embedded Systems, Chapman and Hall/CRC, Editor Insup Lee, Joseph Y-T. Leug and Sang H. Son. pp. 12-1 -12-17. July 2007.

10. Y. Chu and A. Burns, “Supporting Deliberative Real-Time AI Systems: A Fixed Priority Scheduling Approach”. In Proceedings of ECRTS07. pp. 259-268. July 2007.

11. A. J. Wellings and A. Burns, “Real-Time Utilities for Ada 2005”. Reliable Software Technologies - Ada Europe 2007 - Lecture Notes in Computer Science. Volume 4498, pp. 1-14. June 2007.

12. M. Prochazka, R. Ward and A. J. Wellings, “A First Step towards using Real-Time JAVA for Space Craft On-board Software”. Data Systems in Aerospace (DASIA 2007), ESA SP-638. pp. 253-257, May 2007.

13. G. M. A. Lima and A. Burns, “A Priority-based Consensus Protocol”. In Proceedings of the 25th Brazilian Symposium on Computer Networks and Distributed Systems (SBRC 2007). Volume 1, pp. 353-366, May 2007.

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15. P. Emberson and I. Bate, “Minimising Task Migrations and Priority Changes In Mode Transitions”. In Proceedings of the 13th IEEE Real-Time And Embedded Technology And Applications Symposium (RTAS 07). pp. 158-167. April 2007.

16. I. Symeou, “Knowledge-Theoretic Protocols for Wireless Sensor Networks”. In Proceedings of the 3rd IET UK Embedded Forum. pp. 3-9. April 2007.

17. R.I. Davis, A. Burns, R.J. Bril, and J.J. Lukkien. “Controller Area Network (CAN) Schedulability Analysis: Refuted, Revisited and Revised”. Real-Time Systems, Volume 35, Number 3, pp. 239-272, April 2007.

18. A. Burns and T.-M. Lin, “An Engineering Process for the Verification of Real-Time Systems”. Formal Aspects of Computing. Volume 19, Number 1, pp. 111-136. March 2007.

19. Y. Chang and A. J. Wellings, “Hard Real-time Hybrid Garbage Collection with Low Memory Requirements”. In Proceedings of the 27th IEEE Real-Time Systems Symposium. pp. 77-86. December 2006.

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26. D. Kazakov and I. Bate, “Towards New Methods for Developing Real-Time Systems: Automatically Deriving Loop Bounds Using Machine Learning”. In Proceedings of the 11th IEEE International Conference on Emerging Technologies and Factory Automation, Sept. 2006.

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33. Manel Velasco and Pau Martí, “A Preliminary Approach to Feedback Control of Server-based Real-Time Systems” (Poster). In Poster Session, Second IEEE International Workshop on Feedback Control Implementation and Design in Computing Systems and Networks(FeBID07), Munich, Germany, May 2007.

34. Pau Martí and Manel Velasco, “Toward Flexible Scheduling of Real-Time Control Tasks: Reviewing Basic Control Models”. In 10th International Conference on Hybrid Systems: Computation and Control (HSCC07), LNCS 4416, pp. 710–713, April 2007.

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49. A. Antunes, P. Pedreiras, L. Almeida, A. Mota. Dynamic Rate Adaptation: a method to improve operational flexibility in distributed control systems (poster). FeBID 2007, 2nd

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2.3.3 Interaction and Building Excellence between Partners

The expertize within the ART cluster and the interaction among the partners is being extremely helpful for building a general view of the existing embedded systems panorama, with the advantage of perceiving the approaches followed by the partners under different perspectives. This generates interesting discussions that are extremely constructive in the process of integrating several algorithms together in the same system. In some case, such interactions generate new ideas on applying existing algorithms to different domains (e.g., from processor to networks, or viceversa) or extending the algorithms to more general scenarios.

All the partners in the ART cluster actively contributed to the development of a shared operating system platform for testing and evaluating novel kernel mechanisms suitable for supporting adaptive real-time embedded systems.

In particular, the interaction between Pisa, Pavia, Evidence, Aveiro, and Catania was very constructive for defining the characteristics of a small real-time embedded platform for sensory acquisition and motor control, which can also be used (in conjunction with a wireless card) as a node of a mobile wirelss network. Microchip is very interested in commercializing such a product for a number of industrial applications and academic research.

York, Cantabria, Porto, and Madrid (UPM and UC3M) are tightly collaborating in the real-time languages activity, which also involves other international researchers, particularly in the US. One of the main aims of such a collaboration is the development of a web-based repository for Ada 2005 patterns.

Pavia, Pisa, Catania and Aveiro are addressing the issue of achieving flexibility in networked systems through an integrated approach, where several subsystems are encapsulated and later integrated on a shared hardware architecture. This is valuable in many industrial contexts, among which, distributed robotics and automotive. As the network is a resource shared by all subsystems in the distributed architecture, its role in the integration process is particularly important, and the usage of an efficient and flexible network scheduler is essential. The core activity thus focuses on assessing the suitability of Server-CAN, a network scheduler for the Controller Area Network, in the context of subsystem integration.

Philips and TUKL have been working on integrating real-time scheduling and cache management for next generation execution platforms in a joint PhD student project. Together with partners within and outside ARTIST2, TUKL has started work on an EU project on flexible scheduling, which continues the work carried out within the FIRST project.

University of Cantabria is leading the FRESCOR project, which is aimed at developing a framework that integrates advanced flexible scheduling techniques directly into an embedded systems design methodology, covering all the levels involved in the implementation, from the OS primitives, through the middleware, up to the application level. The FRESCOR project brings together a strong consortium of 11 leading members of industry and academia. Six of its partners are university groups that are strong in different research topics in embedded systems, and are members of the ARTIST2 NoE: Cantabria (real-time distributed systems), York (real-time scheduling), SSSA (real-time operating systems), TUKL (flexible and hierarchical scheduling), University of Valentia (embedded real-time operating systems), and Czech Technical University in Prague (network protocols, reconfigurable architectures). The other five partners are industrial companies. Two of them are large companies with different business areas: ENEA is participating as a developer of a real-time operating system and Thales is contributing with their expertise in component-based design methodologies. The other three companies are SMEs with a lot of experience in the area, and they will contribute to the development, evaluation and exploitation of different parts of the project: Visual Tools S.A. on digital media applications, Rapita Systems Ltd on simulation tools, and Evidence srl on real-time kernels for reconfigurable multiprocessor platforms.

UP-Madrid has a tight collaboration with the Universidad of Cantabria for the development of the enhanced version of the RT-EP protocol and for the adaptation of HOLA-QoS to the MaRTE operating system. Similarly, UPM had a close interaction with SSSA for doing the equivalent job on top of the SHARK operating system. UPM has continued its collaboration with UC3M in the development of the improvements of HOLA-QoS and some of the activities on QoS-aware components. Finally, UPM has based the work on RMI-HRT on the definition of a Java profile for high integrity systems done by the University of York.

Universidad Carlos III de Madrid (UC3M) has collaborated in a very close way with the University of Aveiro during this period of time. Two of the members of UC3M have carried out a 5 months stay each at the University of Aveiro to work on the avobe mentioned topics. On one side, the knowledge on real-time communications, sensor networks and fault tolerance of the Aveiro group and, on the other side, the knowledge of middleware architectures, QoS management and RTSJ-RMI of UC3M has been joined. This has allowed the enhancement of the work of UC3M towards the network level in order to build real-time communications and fault-tolerance inside middleware technology. Also, UC3M collaborates continuously with UPM in the enhancement of the HOLA-QoS architecture and on some aspects of QoS-aware component technology.

Technical University of Catalonia had a strong interaction with many ART cluster teams that has taken place with several cluster meetings, visits to other partners' institutions, as well as joint publications in top conferences and journals. The team interacted with the University of Lund to modify the Truetime simulator to better study new feedback scheduling theoretical results. It also interacted with SSSA to implement feedback scheduling mechanisms in the Shark kernel.

The team at the University of Aveiro developed interactions with Pavia concerning a flexible Ethernet network driver to be applied in SHaRK, which, beyond the common immediate packet send and receive services is capable of transmitting packets at predefined instants in time, thus providing improved support for timed protocols, with Catalonia for the design of the "dual-rate switching control" approach that consists in reducing drastically the sampling rate of feedback control loops when they are close to the stationarity to reclaim resources, with Carlos III concerning the development of a dynamic service composition framework in distributed real-time systems and the combination of the FTT paradigm with RMI to improve predictability in this middleware. and with the University of the Balearic Islands, concerning the development and analysis of active hubs for CAN (CANcentrate/ReCANcentrate).

2.3.4 Joint Publications Resulting from these Achievements

1. Giorgio Buttazzo and Anton Cervin, "Comparative Assessment and Evaluation of Jitter Control Methods", Proc. of the 15th International Conference on Real-Time and Network Systems, Nancy, France, March 29-30, 2007.
2. Hoai Hoang and Giorgio Buttazzo, "Reducing Delay and Jitter in Software Control Systems", Proc. of the 15th International Conference on Real-Time and Network Systems, Nancy, France, March 29-30, 2007.
3. Mauro Marinoni and Giorgio Buttazzo, "Elastic DVS Management in Processors with Discrete Voltage/Frequency Modes", IEEE Transactions on Industrial Informatics, Vol. 3, No. 1, pp. 51-62, February 2007.

4. Giorgio Buttazzo, Pau Marti, and Manel Velasco, "Quality-of-Control Management in Overloaded Real-Time Systems", IEEE Transactions on Computers, Vol. 56, No. 2, pp. 253-266, February 2007.

5. Mauro Marinoni, Tullio Facchinetti, Giorgio Buttazzo, and Gianluca Franchino, "An Embedded Real-Time System for Autonomous Flight Control", 50th Int. Congress of ANIPLA on Methodologies for Emerging Technologies in Automation (ANIPLA 2006), Rome, Nov. 2006.

6. G. Buttazzo, G. Chiandussi, C. Demartini, G. Iannizzotto, L. Lo Bello and F. Quagliotti, "Land control and monitoring system for fire prevention", 50th Int. Congress of ANIPLA on Methodologies for Emerging Technologies in Automation (ANIPLA 2006), Rome, Nov. 2006.

7. Mauro Marinoni and Giorgio Buttazzo, "Balancing Energy vs. Performance in Processors with Discrete Voltage/Frequency Modes", Proceedings of the 12th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications, Sydney, Australia, August 2006.

8. Hoai Hoang, Giorgio Buttazzo, Magnus Jonsson, and Stefan Karlsson, "Computing the Minimum EDF Feasible Deadline in Periodic Systems", Proceedings of the 12th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications, Sydney, Australia, August 2006.

9. I. Estévez Ayres, L. Almeida, M. García Valls, and P. Basanta Val. An Architecture to Support Dynamic Service Composition in Distributed Real-Time Systems. Accepted for publication in 10th IEEE International Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing (ISORC 2007). Santorini Island, Greece. May 2007.

10. P. Basanta Val, L. Almeida, M. García Valls, and I. Estévez Ayres. Towards a synchronous scheduling service on top of an unicast distributed real-time Java. Accepted for publication in 13th IEEE Real-time Systems Application Symposium (RTAS' 2007).

11. S. Baruah and A. Burns, “Sustainable Scheduling Analysis”, In Proceedings of the 27th IEEE Real-Time Systems Symposium, pp. 159-168, December 2006.

12. Mario Aldea Rivas and Michael González Harbour. Operating System Support for Execution Time Budgets for Tread Groups. 13th International Real-Time Ada Workshop (IRTAW), Woodstock, VT, USA, April 2007.

13. R. Marau, L. Almeida, P. Pedreiras, M. González Harbour, D. Sangorrín, and J. Medina. Integration of a Flexible Network in a Resource Contracting Framework. IEEE Real-Time and Embedded Technology and Applications Symposium, WiP session, Bellevue, WA, USA, April 2007.

14. Julio L. Medina, Patricia López, José M. Drake, François Terrier and Sèbastien Gerard. A Modeling Approach for the Timing Verification of COTS Components-based Distributed Hard Real-Time Systems. Workshop on Models and Analysis for Automotive Systems (RTSS2006-WMAAS), held in conjuntion with the RTSS-2006, Rio de Janeiro, Brasil, December 2006.

15. I. Estevez-Ayres, L. Almeida, M. Garcia-Valls, P. Basanta-Val. An Architecture to Support Dynamic Service Composition in Distributed Real-Time Systems. 10th IEEE Symp. on Object/component/service-oriented Real-time distributed Computing, ISORC 2007. Santorini, Greece. 7-9 May 2007.

16. P. Basanta-Val, L. Almeida, M. Garcia-Valls, I. Estevez-Ayres. Towards a synchronous scheduling service on top of a unicast distributed real-time Java. 13th IEEE Real-Time and Embedded Applications Symposium, RTAS 2007. Bellevue, USA. 3-6 April 2007.

17. R. Marau, L. Almeida, P. Pedreiras, M. González-Harbour, D. Sangorrín, J. L. Medina. Integration of a flexible network in a resource contracting framework. 13th IEEE Real-Time and Embedded Applications Symposium, RTAS 2007 - Proc. of the Work-in-Progress Session. Bellevue, USA. 3-6 April 2007.

18. G. BUTTAZZO, G. CHIANDUSSI, C. DEMARTINI, G. IANNIZZOTTO, LO BELLO L., F. QUAGLIOTTI. (2006). Land control and monitoring system for fire prevention. In: Methodologies for Emerging Technologies in Automation. 50th International Congress on Methodologies for Emerging Technologies in Automation, ANIPLA 06. 13-15 November 2006. (vol. I). Special Session on Land Monitoring and Control.

2.3.5 Keynotes, Workshops, Tutorials

Keynote talks:

1. "QoS-Based Resource Management"
given by Marisol García Valls
University of Thessaloniki, Greece
May 5th, 2007.

2. “Predictable response times in event-driven real-time systems”
M. González Harbour
Automotive 2006 - Security and Reliability in Automotive Systems, Stuttgart
October, 2006.

3. L. Almeida. Traffic Scheduling Anomalies within Temporal Partitions. Invited Lecture at the Computer Science Departament, University of Pennsylvania, Philadelphia, USA, de 14 de Novembro de 2006.

4. L. Almeida. Brief Tour of Real-Time Embedded Networks. Lecture within the Real-Time Systems Course, Computer Science Departament, University of Pennsylvania, Philadelphia, USA, de 14 de Novembro de 2006.

5. L. Lo Bello, “Open Research Issues in Real-Time Networks”, WIRTES 2007, First Italian Workshop on Real-Time and Embedded Systems, July 2nd, 2007, Pisa, Italy.

6. Pereira, N., "A Prioritized Collision-Free MAC Protocol for Wireless Medium", Carnegie Mellon University, Dec. 2006.

7. Andersson, B., "Real-Time Scheduling on Multiprocessors", Carnegie-Mellon University, Feb. 2007.

8. Andersson, B. "Integration of WiDom in Real-Time Chains", University of Illinois Urbana Champaign, Mar. 2007.

9. Andersson, B., Tovar, E., "Computing Aggregated Quantities Efficiently in Large-Scale Dense Sensor Networks", EU-US Workshop on Wirelessly Networked Embedded Systems Cyber-Physical Systems and Beyond, Edinburgh, UK, July 2007.

10. Dynamic CAN Priorities
Speaker: Josep M. Fuertes
In "CANopen - Applications and markets", July 2, UPC, Barcelona, Spain 2007
http://www.can-cia.org/dates/events/?278

11. Operating Systems, V&V Practical Aspectws, Real-Time Control
Speaker: Josep M. Fuertes
In Professional short course on "Critical software quality assurance: aerospace and industrial applications", 15 to 20 February 2007 in Barcelona, Spain
http://www.ctae.org/downloads/criticalswcourse.pdf

Workshops:

1. First Italian Workshop on Real-Time Embedded Systems
RETIS Lab, Scuola Superiore Sant'Anna, Pisa
July 2, 2007
Organizers: Giorgio Buttazzo, Giuseppe Lipari, Lucia Lo Bello
Objectives: Build an Italian community on real-time embedded systems and favor interactions between Italian industry and academic researchers.
Topics: real-time scheduling, operating systems, sensor networks, design methodologies
Results: The workshop attracted 16 universities and 12 industries working in the field, 28 short presentations were given and participants had time to meet, know each other and exchange information on their research interests. A second workshop is planned for next year.
URL: http://feanor.sssup.it/wirtes07/

2. WCET 2007: Worst Case Execution Time Analysis
RETIS Lab, Scuola Superiore Sant'Anna, Pisa
July 3, 2007
Organizers: Christine Rochange, TRACES group, IRIT, Toulouse, France
Objectives: Bring together people from academia, tool vendors and users in industry that are interested in all aspects of timing analysis for real-time systems.
Topics: Timing analysis, calculation methods for WCET, testing methods for WCET analysis, tools for timing analysis, compiler optimizations for worst-case paths.
Results: The workshop attracted 32 participants from different European countries and technical papers have been published in proceedings.
URL: http://www.irit.fr/wcet2007/

3. RTN 2007: Real-Time Networks
RETIS Lab, Scuola Superiore Sant'Anna, Pisa
July 3, 2007
Organizers: Ye-Qiong Song, LORIA, Nancy, France
Objectives: RTN focuses on the current technological challenges of developing communication infrastructures that are real-time, reliable, pervasive and interoperable.
Topics: Distributed systems, communication protocols, wireless sensor networks, mobile ad-hoc networks.
Results: The workshop attracted 30 participants from different European countries and technical papers have been published in proceedings.
URL: http://rtn2007.loria.fr/

4. OSPERT 2007: Operating Systems Platforms for Embedded Real-Time Applications
RETIS Lab, Scuola Superiore Sant'Anna, Pisa
July 3, 2007
Organizers: Scott A. Brandt, University of California, Santa Cruz, CA, USA and Kevin Elphinstone, University of New South Wales, Kensington, NSW, Australia.
Objectives: This workshop is intended as a forum for researchers and practitioners of RTOS to discuss the recent advances in RTOS technology and the challenges that lie ahead.
Topics: Support for component based development; Scalability, from very small scale

embedded systems to full-fledged OSes; Real-Time on Linux; Interaction with reconfigurable hardware; Support for embedded multi-processor architectures; Security and fault tolerance for embedded real-time systems; Power-aware operating systems..
Results: The workshop attracted 18 participants from different European countries and technical papers have been published in proceedings.
URL: http://www.cs.ucsc.edu/~sbrandt/OSPERT.html

5. X Jornadas de Tiempo Real 2007
Organized by UPC, Barcelona, Spain
Spanish forum for real-time researches
URL: http://congress.cimne.upc.es/JTR2007/

6. International Workshop on Models of Computation and Communication
MoCC, Zurich
November, 2006.

7. NeRES 2007 - ARTIST2 Workshop on Networks for Reconfigurable Embedded Systems
Aveiro, Portugal
April 2007.
Targeted dicussing the network requirements to support reconfigurability in distributed embedded systems, as well as the adequacy of current protocols and middlewares.
URL: http://www.artist-embedded.org/artist/Motivation-and-Goal.html

Tutorials:

1. "MARTE: A New Standard for Modeling and Analysis of Real-Time and Embedded Systems"
RETIS Lab, Scuola Superiore Sant'Anna, Pisa
July 3, 2007
URL: http://feanor.sssup.it/ecrts07/tutorial.shtml

Courses:

1. Course on "Networked and embedded control systems" in the 2nd HYCON PhD School on Hybrid Systems (http://www.dii.unisi.it/hybrid/school07/), organized by the European Network of Excellence "HYCON - Hybrid Control: Taming Heterogeneity and Complexity of Networked Embedded Systems <http://www.ist-hycon.org>" (6th Framework program).

2. L. Almeida, Real-Time Networks for Embedded Control Systems, 1st European South American School on Embedded Systems, Buenos Aires, Argentina, 8 hours lecture, 21 to 24 August 2007.

3. L. Almeida, Real-Time Networks for Distributed Embedded Systems, University of Pisa, Italy, 8 hours lecture and 4 hours laboratory, 2 to 4 May 2007.

4. L. Almeida. A Holistic View at the Real-Time Issues within Robotic Soccer. Seminar at the Universidad Nacional del Sur, Bahia Blanca, Argentina, 17 August 2007.

5. L. Almeida. A Holistic View at the Real-Time Issues within Robotic Soccer. Seminar at the Zhejiang University, Hangzhou, China, 28 June 2007.

6. L. Almeida. CAN and the challenge of designing Safety-critical automotive systems. Seminar at the Linköping University, Linköping, Sweden, 11 June 2007.

7. L. Almeida. Towards Flexible Distributed Computer Control Systems. Seminar at the Halmstad University, Halmstad, Sweden, 14 May 2007.

8. L. Almeida. Designing Distributed Real-time Systems: a Focus on Holistic Time-Triggered Design. Lecture within the Real-Time Systems Course, Computer Science Departament, University of Pennsylvania, Philadelphia, USA, de 28 de Novembro de 2006.

Competitions:

1. L. Almeida, N. Lau, P. Pedreiras and A. Pereira. CyberMouse@RTSS2006, Rio de Janeiro, Brazil, Dec 2006. Students design competition within the scope of RTSS 2006. Similar to a satellite workshop but targetting students and where students have to develop the control software for a small robot and run it against the other teams. http://www.ieeta.pt/~lau/web_ciberRTSS/

Contribution to Standards:

POSIX

The University of Cantabria (UC) has continued participation in the POSIX standard. There is currently a new revision of the standard being produced with technical corrigenda, and the UC participates in the debate and ballot process. Initial steps have been taken in the Real-Time System Services Working Group to start a revision of the POSIX.13 standard that defines the real-time profiles. The UC is also participating in the revision of the POSIX-Ada bindings, which is a project that is just starting.

OMG–MARTE

In this period we continue working in the technical activities of the OMG, attending the Technical Meeting in San Diego from 26 to 30 March 2007, and sending a preliminary submission in response to the UML Profile for Modeling and Analysis of Real-Time and Embedded systems (MARTE) request for proposals. The submission was presented to the RTESS (Real-Time Embedded and Specialized Systems) Platform Task Force and was very well received. The standard has now been approved.

UC will continue to work in the Finalization Task Force of the UML Profile for Modeling and Analysis of Real-Time and Embedded systems (MARTE), in order to solve the issues that may be raised by the industrial community about MARTE, and ensure its applicability in the modeling of platforms that can deal with flexible scheduling technologies.

3. Future Work and Evolution

3.1 Problem to be Tackled over the next 12 months (Sept 2007 – Aug 2008)

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.

The main objective is to develop a compositional real-time scheduling framework so that global (system-level) timing properties can be established by composing independently specified and analyzed local (component-level) timing properties. There are two essential problems in developing such a framework: (1) to abstract the collective real-time requirements of a component as a single real-time requirement and (2) to compose the component demand abstractions into system-level real-time requirements. Real-Time system components will include schedulers, aperiodic servers, and resource sharing protocols, which must be put together preserving their properties.

To build software systems out of reusable components, we need a way of specifying what a component should look like through a component model. A component model supports modularity of the software in the sense that it defines what should be hidden in a component such that it can be replaced or reused in several systems. Furthermore, a component model should enforce information hiding, implying that the deployers of a component should not realize when a manufacturer changes the component internals.

A good model should abstract the irrelevant details, focusing on timing properties and resource requirements of the system components. Each component has functional and non-functional parameters, some of them used for the composition.

In our framework, a component will be defined as a self contained unit encapsulating a specific kernel subsystem. Complex components are decomposed into sub-components that implement an atomic functionality within the subsystem under consideration.

Scheduling components are used to schedule tasks or serve aperiodic requests using an aperiodic server. In general, the implementation of a scheduling algorithm should possibly be independent on resource access protocol, and handle only scheduling behaviour. Nevertheless, the implementation of an aperiodic server relies on the presence of another scheduling component (for example, a Deferrable Server can be used if the base scheduling algorithm is Rate Monotonic or EDF, but not Round Robin). Such a design choice reflects the traditional approach followed in the literature, where most aperiodic servers insert their tasks directly into the scheduling queues of the scheduling algorithm. Again, the approach we propose hides such a mechanism with the task models: an aperiodic server must use a task model to insert its tasks into the ready queue of an upper level component (i.e., the scheduler).

Some protocols (like Priority Inheritance or Priority Ceiling) directly interact with the scheduler, since a low-priority task can inherit the priority from a high-priority task, making the protocol dependent on a particular scheduling algorithm. Although a solution based on a direct interaction between the scheduler and the resource protocol is efficient in terms of runtime overhead, it limits the full modularity of the kernel, preventing the substitution of a scheduling algorithm with another one handling the same task model.

3.2 Current and Future Milestones

We are currently working on identifying the problems to be solved for developing a component-based real-time operating system.

We will mainly focus on defining the desired features and critical problems that need to be solved at the technical level to decouple kernel mechanisms between them and from the application. We will also address the problem of extending current RTOSs for uniprocessors to multicore devices, with the objective of making optimal usage of the CPUs available, as well as minimizing power consumption.

3.3 Indicators for Integration

The indicators for integration will be of different kinds, including:

- real-time control applications developed by the joint collaboration among partners, each focusing on a different aspect (e.g., control, scheduling, analysis, languages, etc.) related to his peculiar expertize;
- specific scheduling and resource modules developed by the partners and integrated in the kernel;
- new device drivers developed for the Shark kernel by the cluster members;
- joint publications of research papers;
- joint events (e.g., workshops, summer schools, graduate courses, etc.) organized by the cluster members to spread real-time technologies.

3.4 Main Funding

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

National project PRIN-MIUR 2004: “Real-Time Operating Systems for Supporting Cooperating Autonomous Robots”. Project No. 2004095094_003.

European Strep project: “FRESCOR - Framework for Real-Time Embedded Systems based on Contracts”.

4. Internal Reviewers for this Deliverable

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