Year 2 Review Brussels, February 12th, 2010

Cluster

Achievements and Perspectives:

Operating Systems and Networks

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leader : Giorgio Buttazzo

Scuola Superiore Sant'Anna, Pisa, Italy





> Objectives

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Partners and activities

> Achievements

Future plan



Embedded Systems

are becoming more complex, and characterized by <u>dynamic behavior</u> and <u>distributed organization</u>



RTOSs are still the same as 20 years ago

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Complex applications are developed on top of kernels unsuited for supporting such features



Cluster objectives

Provide a more efficient and predictable support (at the OS and Network level) to the development of future embedded systems. In particular:

- Allow simple and flexible <u>resource management</u> to control the growing complexity;
- Take advantage of <u>multi-core platforms</u>;

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- Support <u>distributed computing</u> to deal with the ubiquitous nature of the computing infrastructure;
- Increase system <u>adaptivity</u> to react to environmental changes.



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Partners

Role

SEVENTH FRAMEWORK PROGRAMME

Core Partners SSSA, Pisa (leader) Univ. of Aveiro TU Kaiserslautern Univ. of Cantabria Univ. of York Univ. of York Univ. of Lund PI Porto IMEC	RT scheduling and RT kernels networking, distributed applications video streaming, off-line scheduling schedulability analysis and OS standards fixed priority scheduling real-time and control issues heterogeneous networks Low power and memory management	
Windriver Microchip Technology NXP Evidence UP Catalonia Univ. of Catania Univ. of Dresden Univ. of Madrid Univ. of Pavia Univ. of Valencia	RT operating systems Embedded applications QoS management in multimedia systems kernels and tools for RT systems control methodologies for RT systems distributed systems Microkernel architectures QoS and resource management RT applications and kernels Real-time and control issues	
Univ. of Balearic Islands	Dependable RT distributed systems	

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Geographical distribution of the cluster partners

- Core partners
- Affiliated partners
- Other partners



Additional International Partners

University of Illinois at Urbana-Champaign

Contacts:	Lui Sha, Tarek Abdelzaher, Marco Caccamo
Topics:	Sensor networks, RT scheduling and control

University of Virginia

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Contacts:	John Stankovic, Sang Son
Topics:	Sensor networks and RT data management

University of North Carolina at Chapel Hill

Contacts:	Sanjoy Baruah, James Anderson, Kevin Jeffay
Topics:	Multi-processor scheduling, multimedia systems

Carnegie Mellon University

- Contacts: Ragunathan Rajkumar, John Lehoczky
- Topics: Resource reservations, QoS management



Spreading Excellence – Year 2

Workshops and Conferences

Events initiated and steered by the cluster

•OSPERT: Workshop on Op. Sys. Platforms for Emb. RT applications •RTN: Int. Workshop on RT Networks

Events strategically steered by the cluster

- •ECRTS: Euromicro Conf. on RT Systems.
- •RTSS: IEEE RT Systems Symposium.

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- •RTAS: IEEE RT and Embedded Tech. and App. Symposium.
- •ETFA: IEEE Int. Conf. on Emerging Tech. and Fact. Automation.
- •HSCC: ACM Int. Conf. on Hybrid Systems: Computation and Control.
- •CRTS: Int. Wks. on Compos. Theory and Tech. for RT Emb. Systems.

Major conferences have Special Issues on the International Journal of Real-Time Systems (Springer)



Ontint Spreading Excellence – Year 2

Summer School

Graduate Course on Embedded Control Systems: Theory and Practice *Scuola Superiore Sant'Anna, Pisa, Italy – June 8-12, 2009* •Giorgio Buttazzo - Scuola Superiore Sant'Anna, Italy

•Karl-Erik Arzen - Lund University, Sweden

•Luis Almeida - University of Porto, Portugal

Educational Platform for Embedded Contorol Systems

Pisa, Pavia, Evidence, Microchip Technology, Embedded Solutions



- Fast prototyping RT control applications
- Facing RT scheduling issues
- Handling resource management
- Used in graduate courses





Cluster activities

Real-Time Networks

Scheduling and Resource Management

Resource Aware Operating Systems



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Achievements and Perspectives:

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Resource-Aware Operating Systems

Activity leader: Giorgio Buttazzo Scuola Superiore Sant'Anna Pisa, Italy





Investigate novel kernel methodologies to make operating systems more

- predictable (in terms of timing behavior)
- efficient (in terms of resource usage)
- robust (to tolerate overload conditions)
- easy to use (to simplify user interface)



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Activity: Resource-Aware Operating Systems

Outcomes from Year 2

- 19 publications from individual groups
- 17 joint publications
- > 4 Workshops/Tutorials
- 6 joint projects (ACTORS, IRMOS, PREDATOR, FRESCOR, WASP, ILAND)
- Industrial collaborations with

Airbus, Bosch, Ericsson, Philips, NXP, Windriver, Intecs, Microchip Technology, Evidence, Embedded Solutions



Main Technical Achievements (1)

Deadline Scheduling on Linux (*Pisa, Evidence*)

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The Linux kernel has been extended to support:

•<u>Earliest Deadline First (EDF)</u> scheduling of periodic tasks (POSIX compliant scheduling class)

•<u>Resource Reservations</u> and <u>Bandwidth Control</u>, through a Constant Bandwidth Server (CBS).



Main Technical Achievements (1)

Deadline Scheduling on Linux (Pisa, Evidence)

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Main Technical Achievements (2)

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Partitioning RT applications on multi-core platforms



Main Technical Achievements (2)

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Main Technical Achievements (3)

Simulation of RT applications

(Pisa, Bologna, Saarland, Dortmund)

The Erika RT kernel has been ported on the MPARM emulator to evaluate the effect of different architecture solutions and resource management policies on real-time applications.

MPARM is a cycle-accurate emulation environment for multiprocessor architectures.

It was configured to evaluate the cache related interference of different scheduling policies on an ARM7 platform.



artir Main Technical Achievements (3) **Simulation of RT applications** (Pisa, Bologna, Saarland, Dortmund) RT Appl. **MPARM ARM7** Core **ERIKA I-Cache D-Cache** SRAM **AMBA Bus** Disturbing Disturbing Disturbing Core 1 Core 2 Core 9

SEVENTH FRAMEWORK

Educational platform for Embedded Systems

Partners:

Pisa, Pavia, Evidence, Microchip Technology, Embedded Solutions



- Flex board dsPic microcontroller
- Erika RT kernel
- Applications in C languages

New applications:

- Robot coordination;
- RT signal processing;
- Inertial Unit;

- Segway control;
- Localization module;
- Monitoring power consumption.



Educational platform for Embedded Systems

Partners:

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Pisa, Pavia, Evidence, Microchip Technology, Embedded Solutions







- Continue the development of software modules to support real-time control applications on the educational kit.
- Investigate a method for positioning preemption points in the task code to reduce the cache related delays.
- Consider the effect of shared resources and nonpreemptive regions in resource reservations.
- Extend the Erika kernel to support the development of realtime applications with energy constraints.
- Evaluate partitioning algorithms on multi-core platforms, and investigate the allocation of dynamic applications with highly variable resource requirements.



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Scheduling and Resource Management

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Activity leader: Alan Burns University of York York, UK





> Provide Policies

For effective resource usage

Provide Analysis

- For predicting system behaviour
- Simulation, scheduling analysis, measurement, model checking

> Provide Models

- For composing systems
- Time triggered and event-triggered work flow
- For static and dynamic usage patterns





To move from single processor platforms to <u>multiprocessor</u>, <u>multi-core</u>, <u>FPGA</u>, etc.

To integrate various resources and abstract views of the overall system

Integrate policies

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- Integrate analysis
- Integrate models





Highlights (stats)

- 18 TAs technical achievements
- ✤ 55 papers from individual sites
- 29 joint papers
 - i.e. more than one site
 - Much higher number than last year
- 10 new projects
 - National and international





- Created the Taxonomy on resource usage
 - Structure agreed

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- Content beginning to added
- Extend the use of hierarchical and contract-based scheduling to multi-resource systems TA2
- Produce effective scheduling and placement algorithms for multiprocessor systems – TAs 7,9,15 & 16
- Extend sensitivity analysis to EDF and multiprocessor systems





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- Produce mode change algorithms suitable for multiprocessor systems – TA11
- Determine an effective way of undertaking (static) architectural tradeoffs INDEXYS project
- Determine an effective way of undertaking (dynamic) adaptive resource management TAs 5,6,10,12, 13,14
- Define a framework that can accommodate multiple time-frames within a single system and facilitate hierarchical scheduling, cascade control and other means of separating temporal concerns – TA1



Sensitivity Analysis for EDF

- Explore parameter space
 - For an unschedulable system what needs to be changed to make the system schedulable
 - > For a schedulable system how much slack is there
 - Consider task execution time, deadline r period. Also processor speed changes



Sensitivity Analysis for EDF

- Traditional EDF scheduling analysis requires all deadlines in a potentially large interval (0,L) to be checked – processor demand analysis (PDA)
- Recently QPA developed that work back from L to 0 checking a minimum number of points (for example 32 rather than 10,000)
- QPA has now been adapted to undertake sensitivity analysis in a one pass – start at L with unschedulable system, at each failure point change parameter(s), at time 0 system is 'just' schedulable.



Plans for Year 3

Continue productive exchange of ideas across the Network, and the wide diversity of work on scheduling

Grow the <u>taxonomy of resource management</u> that will

Be a useful information source

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- > Address multi-resource management
- Address the integration of policies, analysis and models



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Real-Time Networks

Activity leader: Luis Almeida

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The increasing trend for **Networked Embedded Systems**

Wireless Sensor Networks



Data aggregation

Timeliness aspects



Technical results from Year 2

Wireless Sensor Networks

- Timeliness in Wireless Sensor Networks
 - Generalized notion of timeliness suited to WSN (TUKL, CSEM, Philips)
 - e2e delays and # of hops in geographic(/opportunistic) routing (Pisa)
 - Tuning WSN protocols with optimization (York)
 - Analysis in cluster-tree WSN with mobile sinks (Porto, Prague)
 - Hidden node avoidance mechanism (H-Name) for WSN (Porto)
- Mobility issues in ad-hoc real-time wireless communication
 - Middleware for cooperation among mobile units (Aveiro, UnivPorto)
 - Graceful degradation in 802.11 RT communic. (UnivPorto, Zaragoza)
 - Localization/navigation based on RSSI (UnivPorto, Aveiro, UZhejiang)
 - CyberRescue@RTSS2009 students compet. (Pavia, Aveiro, UnivPorto)

SEVENTH FRAMEWORK

Technical results from Year 2

Networked Embedded Systems

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- Robust communication with star topologies
 - Bus-Star quantitative error-containment comparison (Mallorca, UnivPorto)
 - Server-based traffic scheduling within Ethernet switches (Aveiro, UnivPorto, Mälardalen)
- Real-time support to middleware and composability
 - RT improvements to distribution middlewares based on CORBA, Ada DSA, DDS and DRTSJ (Cantabria. Madrid, Bilbao, UnivPorto)
 - Functional composition mechanisms (service-oriented) (Madrid)
- Analysis for specific networks
 - Evaluation of DC powerline communications (Pavia, Aveiro, Mälardalen)
 - Analysis of token-passing networks (Pisa)
 - Control-based traffic scheduling in CAN (Catalonia)



Technical results from Year 2

Specific application domains

- Wireless networks in industrial environments
 - Assessment of cross-channel interference in industrial 802.15.4 networks (Catania)
 - Analysis of 802.11e for RT traffic in industrial automation (Catania)
 - 802.11 / 802.15.4 two-tier architecture for industrial automation (Catania)
- Supporting Intelligent Transportation Systems
 - Architecture for an urban mobility information system (Pisa, Evidence)
- Networked Embedded Systems for Healthcare
 - Platform for physical activity assessment in diverse environ. (Catania)
 - New project to monitor patients with heart diseases (Pisa, Evidence)



Summary of outcomes from Year 2

- > 31 publications from individual groups (8 in journals)
- > 26 joint publications (8 in journals)
- 3 workshops (RTN, APRES, SensorNets)
- > 8 seminars (4 in schools, 2 in workshops, 2 in specific events)
- ➤ 4 tutorials (1 in conference and 3 in schools)
- Continued participation in the TinyOS Net2 Working Group (Open-ZB stack)
- 6 joint projects FP6/7-STREP (FlexWARE, WASP), ARTEMIS (iLAND, EMMON, INDEXYS), ITEA2 (EVOLVE), all with strong industrial participation
- Industrial collaborations with

Critical Software (P), Visual Tools (E), Trialog (F), Magneti-Marelli (I), Yamar (IR), STMicroelectronics (I), NXP (NL)



Plans for Y3

- To continue the work towards a taxonomy of: (continuation) WSNs and MANETs for time-sensitive applications
 - initial draft by Porto, currently being edited by UnivPorto and Catania, to be circulated by others soon

Flexibility in Networked Embedded Systems

- Merged with a similar effort of the activity on Design for Adaptivity, work based on a wiki
- Summer school on RT Networks and participation in other similar schools.
- Continue the sequence of networking related workshops co-located with major events in the Real-Time and Embedded communities (RTN, APRES...)
- Further networked embedded systems educational tools Refinement of CyberRescue tools (MANET) / more tools for WSN and NES
- Contributions to communication protocols and middleware, their application and analysis

RT issues in WSN, star topologies, MANET, distribution middlewares...

