



**Research Centre in  
Real-Time Computing Systems**  
FCT Research Unit 608

# **Annual Report 2009**





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## EXECUTIVE SUMMARY

The CISTER Research Unit is based upon the IPP-HURRAY Research Group (HUGging Real-time and Reliable Architectures for computing sYstems), which was created in 1997, and has since grown to become the most prominent research group of the School of Engineering (ISEP) of the Polytechnic Institute of Porto (IPP), and one of the leading International research groups in the area of real-time computing systems.

In both the 2003 and 2007 evaluations, the Unit was granted the classification of 'Excellent' from an international panel of experts. We firmly believe that ever since then, and particularly during 2009, we have been exceeding the expectations placed on us. The strategy set down by the Unit has been definitely towards top-quality research, able to compete with the best international groups in our research areas.

The strategy set down by CISTER has been definitely towards top-quality research, able to compete with the best international groups in our research areas. The goal of the unit is to continue (and reinforce) to be one the International leaders of research in real-time embedded systems. This objective is aligned with the growing strategic importance of embedded systems in Europe, and the role that needs to be played in the international research landscape of the area.

## MANAGEMENT STRUCTURE

The unit has a Director, the Unit leader, and two Vice Directors. Together these form the Board of Directors (BoD).

The main responsibilities of the Director are: to represent externally the Unit; to manage and co-ordinate the activities of the Unit; to co-ordinate the definition of the plan of activities and budget; and to present the plan of activities, budget and yearly report (scientific and financial) to the Unit's Steering Committee and Executive Boards. The main responsibilities of the Vice Directors are to assist and replace the Director when necessary.

The BoD is assisted in governance by an Executive Board (ExecB), to manage day-to-day activities. The ExecB is structured by areas of responsibilities: (i) Finances, Quality & Procedures; (ii) Human Resources; (iii) Research Projects; (iv) Industry Contracts, IP-issues (v) Presentation & Image; (vi) Infrastructures & Facilities; (vii) IT Infrastructure and (viii) Administrative Support. These responsibilities are associated with individuals in the ExecB.

The Steering Committee (SC) supports the BoD in contributing to the medium to long term strategic planning of the CISTER Research Unit. This includes providing direct input to the half yearly budget planning process, as well as reviewing the resulting overall budget. It is also involved in planning the opening or closure of research areas. Additionally, the SC supports the BoD in the selection process and management of research staff and students. The SC includes the ExecB members and the research leaders.

The activities of the Unit are periodically reviewed by international top-ranked researchers. Annually, a number of on-site visits are performed by these researchers to discuss the Unit's activities and plans. The Unit has also been actively endorsing and driving bilateral research workshops with top research centres. These have been extremely useful as well in providing inputs for research plans and strategy.

## CISTER IN NUMBERS

In the year of 2009, the CISTER research team was composed by:

- Number of Researchers holding a PhD: 14
- Number of Researchers holding a MSc: 12

In 2009 the unit had around 383K EUR of competitive funding. During 2009 CISTER had 4 international and industrial driven projects, and 3 fundamental research projects (FCT supported) running.

In 2009 CISTER got approved a set of new projects, accounting for a budget of 82K EUR in the year, with a total budget of 247K EUR.

## GENERAL OBJECTIVES

The CISTER Research Unit focuses its activity in the analysis, design and implementation of real-time computing systems (RTS). In RTS, correctness depends not only on the logical result of computation, but also on the time at which the results are produced. Thus correctness and performance are very tightly interrelated. In recent years an increased pervasiveness of embedded systems in general and large-scale distributed systems in particular has emerged. This has introduced real-time concerns into mainstream enterprises, with clients in a wide variety of industries and academic disciplines.

The strategy adopted by the Unit is the pursuit of excellence in research which is benchmarked against the best international groups in our research areas. These include the most prestigious research groups in Europe (e.g. York, UK; SSSUP, Italy; MdH, Sweden; TUW, Austria), the U.S. (e.g. UNC-CH; UIUC; UVA; WUSTL; CMU), and Asia (e.g. KAIST, South Korea). This is just a sample of prestigious institutions with whom we collaborate, but also with whom we compete in the advancement of the state-of-the-art in real-time computing systems. Despite our relatively small dimension, we have produced cutting-edge and seminal research. The results have been recognised by our peers as world class.

There are four key strategic options that have been driving the research agenda of the Unit: (i) sustained growing and research focus; (ii) selective and demanding publication efforts; as a consequence of the two previous, (iii) selective, demanding and consistent participation of key Unit's researchers in scientific service; and finally, as a consequence of the three previous, (iv) a strong participation in international reputed academic/industrial research partnerships with focus both on fundamental and applied research.

The continued focus and excellence of CISTER's research is supported through the Unit's definition of a few, but strategic research areas: Wireless Sensor Networks; Multicore Systems; Cyber-Physical Systems; Adaptive Real-Time Systems; and Real-Time Software.

In line with the strategy of research excellence, CISTER researchers aim and succeed to publish in highly reputed, peer-reviewed, international journals, as well as top conferences in the respective fields, many of which have higher impact than top journals.

Aligned with its development plan, the CISTER started in 2009 to actively collaborate in the ECE PhD program at FEUP, where CISTER leads and coordinates a course stream on embedded and real-time computing systems. Also related to PhD studies, the research unit launched 2 calls. In these more than 150 students applied, with more than a third of applicants having marks equivalent of 15 or better in the bachelor / master degrees. A rigorous selection process has led to the selection of 10 promising new PhD students coming from Russia, Mexico, India, Cuba, Iran, Pakistan and Portugal.

## MAIN ACHIEVEMENTS

CISTER has been achieving international leadership in its activities, as demonstrated by the research results, presented in the research group section, and started initiatives.

In 2009 CISTER started two projects, REWIN and REHEAT, funded by FCT, addressing the satisfaction of real-time requirements when resources are shared, either in a wireless channel or in heterogeneous multiprocessors. CISTER also participates in RECOMP, an ARTEMIS project, due to start in 2010, jointly funded by the Portuguese Government and the European Commission. RECOMP will be executed by a consortium comprised of 41 industrial/academic partners, and is one of the biggest R&D European project, with an overall budget of 25 M€. The project will establish methods, tools and platforms for enabling cost-efficient certification and re-certification of safety-critical systems.

CISTER has driven the proposal and is now actively participating (WP4 “communication & protocols” leader) in the ARTEMIS project EMMON on large-scale embedded monitoring using Wireless Sensor Networks (WSN). EMMON pushes the state-of-the-art targeting a real-world deployment with 10000 nodes (one order of magnitude higher than the largest deployed so far). For this, CISTER has been devising a network architecture coping with QoS properties, as well as over the air programming and data aggregation algorithms.

CISTER was in the genesis and is one of the core partners in the European NoE on Cooperating Objects (CONET), leading WP5 “Spreading of Excellence”, and the COTS4QoS and SDP research clusters. The COTS4QoS research cluster aims at designing building blocks for supporting QoS in WSNs using off-the-shelf technologies, while SDP targets distributed algorithms for computing aggregated quantities (such as MIN, MAX, AVERAGE) of sensor readings and achieve this across different sensor networks.

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CISTER researchers published several papers in highly reputed, peer-reviewed, journals in the year 2009. Among them a paper in the Real-Time Systems Journal, and two papers in SIGBED review. It is worth noting that the former was invited for publication on account of being one of the top ranked papers in a highly reputed real-time systems' conference (ECRTS 2008), while the latter two were invited on account of being in the top 5 Work-in-Progress papers in yet another highly reputed conference (RTSS 2009). CISTER maintains a regular publication record and, notably, has had regular conference papers accepted at the premiere real-time systems event (RTSS) every year since 2005, and in particular two papers accepted in 2009.

In the emerging Cyber-Physical Systems (CPS) area, we have been assuming a prominent role. Researchers of the group have addressing distributed algorithms that exploit dominance-based MAC protocols [O2,O4], which provide unprecedented advantages for WSNs, as aggregate computations (data aggregation, interpolation) can be performed with time complexity independent of the number of nodes, greatly leveraging scalability. This is a key feature, core on a project proposal, SmartSkin, led by the group, with partners Critical Materials and Embraer, for reducing fuel consumption in aircrafts by reducing drag. Also in the area of CPS, we started a partnership with PT and CMU to use CPS technologies for energy-optimized data centers, typically voracious of energy and cooling.

In the Wireless Sensor Networks (WSN) area, the group has been leading R&D in IEEE 802.15.4 and ZigBee technologies and provided methodologies to analyze and engineer WSNs with improved QoS [J2, O9, O12, O22,]. This fostered group of researchers to create (together with TKN-TUB researchers) the TinyOS 15.4

and ZigBee Working Groups. Notably, group researcher Ricardo Severino received the EWSN/CONET'09 MSc Thesis Award. In 2009, we have also finalized the migration of the open-ZB protocol stack implementation to the ERIKA real-time operating system, as a result of collaboration with the RETIS Lab at SSSUP (Pisa, Italy).

The current use of software as the key component of any real-time embedded system is increasing the, often contradictory, demands for attributes such as flexibility, adaptation, isolation, reliability or availability. In the Real-Time Software area, group researchers have specified a middleware for cooperative distributed systems [J1], with decentralized coordination models and QoS constraints [O10], in the scope of the CooperatES project and have actively participated in a joint effort (project RESCUE with UBI, FCUP and UMinho) to integrate concurrency models with software verification approaches in embedded systems.

In the Adaptive Real-Time Systems area, group researchers have extended the adaptive approach of [J1] with a one-step decentralised coordination model based on feedback mechanisms to reduce the complexity of interactions among dependent nodes [O10]. Group researchers have also developed in cooperation with the University of Pennsylvania a tool to perform compositional real-time analysis in particular in the context of hierarchical real-time systems, which are suitable for open real-time environments. Temporal isolation and adaptation has finally been addressed in joint work with the Australian research centre NICTA [O11].

In the Multicore Systems area, group researchers are developing advanced scheduling algorithms. Specifically, we have created (i) algorithms with the ability to schedule tasks to meet deadlines even at high processor utilization and even with few preemptions [O1,O15], (ii) algorithms with the ability to schedule tasks to meet deadlines even when they share other resources (for example I/O devices) [O21] and (iii) algorithms for scheduling software systems with ability to reconfigure by changing from one operational mode to another [O3]. Due to the importance of these results, the research has led to highly visible publications with two regular papers at IEEE RTSS [O15,O21], the premiere publication venue in area of real-time systems.

Group researchers also participated in the organisation of several international events, and participated as PC Chairs in three workshops, co-located with the major events in the real-time systems area (RTSS 2009 and ECRTS 2009). Also, CISTER co-organized the First International School on Cyber-Physical and Sensor Networks (SensorNets 2009), which attracted over 100 participants from 20 countries.

## ACTIVITIES

### INTEGRATIVE/MULTIDISCIPLINARY ACTIVITIES

As the Unit is relatively small, its areas of research are by their nature multidisciplinary. The unit has strategically fostered the integration of researchers from different background areas with the goal of setting up a team with focused and complementary competencies.

This policy was continued during 2009, particularly by the strategic hiring of researchers in the area of hierarchical systems, as well as power management and operating systems. CISTER includes researchers with diverse academic backgrounds, such as Electrical and Computer Engineering, Informatics Engineering, Computer Science and Applied Physics/Mathematics.

These complementary backgrounds allowed increasing the capabilities of the Unit, through research initiatives that encompassed hardware and software integration, vertical frameworks, ranging from lower level issues such as hardware platforms for sensor network communication to higher level design, such as applications and test-beds. Utilising this, the Unit leads international research in embedded real-time systems, attacking emerging challenges in a focused manner through its research areas.

Wireless Sensor Networks experience the transition from research to industrial deployment. During this transition new challenges appear in link quality management and general communication paradigms to scale small deployments to 1000s of nodes in a reliable and energy efficient manner. In Cyber-Physical Systems, the computer systems do not only compute quantities, but are also tightly integrated and interacting with their physical environment, by taking sensor readings and acting on it. Such systems require a rethinking in the usual computing and networking concepts, while the importance of timeliness is increasing steadily.

Another trend is towards massively networked embedded computing devices. Such extreme networking poses considerable technical challenges in terms of the distributed programming paradigms not reflected in current languages. Real-Time Software is concerned with the management of software concurrency, as well as decentralised middleware and operating system adaptation, which form fundamental building blocks of autonomic distributed systems.

Adaptive Real-Time Systems address the emergence of embedded devices exposed to different levels of criticality, reconfigurable and mobile systems. This is reflected in the work on server-based scheduling, adaptive service management, hierarchical systems, as well power management of energy constrained embedded systems. A final trend addressed by the group is the increased deployment of Multicore Systems and the inherent challenges in providing solutions, which are able to support real-time guarantees, considering both identical and heterogeneous multicores.

The research unit is involved in a number of national and international projects that are multi-site and multi-disciplinary; e.g. RESCUE, EMMON and RECOMP, or the ArtistDesign and CONET networks of excellence.

### OUTREACH ACTIVITIES

The CISTER Research Unit has been devoting a special attention to outreach activities, trying to leverage synergies between our scientific achievements and society, both in a broader sense (public in general) as well as in more specific niches (e.g. Portuguese industrial community and secondary school students). Visits from secondary schools or universities to our applied research labs are very frequent. The Unit also regularly participates in workshops organised by its hosting institutions ISEP and IPP, which aim at

disseminating ongoing education and research to all ISEP/IPP but also the general public, namely to potential candidates to our engineering degrees.

Most of our fundamental research activities are supported by applied research vertices, which facilitates that CISTER scientific results are accessible to the general public through practical demonstrations with state-of-the-art technology and appealing application scenarios (e.g. RFieldbus manufacturing automation field-trial, <http://www.cister.isep.ipp.pt/rfpilot> and ART-WiSe search&rescue testbed - <http://www.cister.isep.ipp.pt/ART-WiSe/testbed.php>).

Also, during 2009 CISTER organized a series of seminar talks and distinguished lectures. The talks involved several senior researchers and PhD students from CISTER, and were well attended by not only students and faculty members of Instituto Superior de Engenharia do Porto, but also by members of the Faculdade de Engenharia of University do Porto (FEUP). During the year we organized distinguished lectures by highly reputed academics and industrial researchers like Professor Alan Burns (University of York, UK), Stamatis Karnouskos (SAP Research, Germany) and Professor Luis Almeida (FEUP, Porto). CISTER researchers have also participated in similar initiatives of other institutions, with the invited talk "Real-time scheduling on multicores" within the "Back-to-Basics" distinguished invited researcher's seminar of FEUP.

CISTER strategy was also to reinforce collaborations with industry. This is achieved through projects within ARTEMIS, where we have been successful in the EMMON project in 2008 (started in 2009), the RECOMP project (approved in 2009, starting 2010) as well as proposals currently in preparation. Also internationally, SAP, Schneider Electric, and Telecom Italia are participating with us in competitive third-party-funded research projects such as CONET.

CISTER has also pursued outreach via exploration of industry contacts in Europe, as demonstrated by a visit to Intel Munich and preparation of a research proposal with European Microsoft Innovation Centre in Aachen.

CISTER researchers have taken on teaching roles in the University of Porto, doctoral program in electrical and computer engineering (PDEEC). 2 of the 4 courses co-taught by CISTER researchers were conducted in Fall 2009. And we have also been very successful in engaging students with our activities. That is the case of the BII scholarships we have been granting.

## ORGANIZATION OF CONFERENCES

By integrating the top-ranked scientific community in the real-time and embedded systems area, the Unit regularly organizes scientific events related to those scientific topics.

Particularly noteworthy were the participation as PC Chairs in ARTISTDesign (FP7-NoE) supported workshops:

- Workshop on Compositional Theory and Technology for Real-Time Embedded Systems (<http://www.artist-embedded.org/artist/CRTS-2009.html>), co-located with RTSS 2009.
- Workshop on Operating Systems Platforms for Embedded Real-Time Applications (<http://www.artist-embedded.org/artist/-OSPERS-2009-.html>), co-located with ECRTS 2009
- Workshop on Real-Time Networks (<http://www.cister.isep.ipp.pt/rtn09/index.php>), co-located with ECRTS 2009

The group also co-organized the First International School on Cyber-Physical and Sensor Networks - SensorNets 2009 (<http://www.sensornets-school.org>) which attracted over 100 participants from 20

countries, and provided tutorials in the international events EWSN'09, ETTX'09, CONET'09 and SensorNets.

Senior researchers of the group were also called upon to serve on program committees of reputed conferences, in some cases several researchers at the same time: IEEE RTSS, IEEE RTAS, ECRTS, IEEE RTCSA, IEEE EFTA, IEEE ICDCS, ACM SAC, OPODIS, IFAC FET, IFIP DIPES, Ada-Europe, among others. One researcher is since 2007 editor for Real-Time and Embedded Systems for the Journal of Systems Architecture: Embedded Software Design (JSA) and another researcher is since June 2007 Editor-in-Chief of the Ada User Journal.

In National events, the group participates in the steering committee of the INFORUM, the Portuguese Symposium in Informatics, and has co-organized the Real-Time and Embedded Workshop of the symposium (<http://inforum.org.pt/INForum2009/sessoes/sistemas-embebidos-e-de-tempo2010real>).

### INDUSTRY CONTRACT RESEARCH

The group has engaged on a series of prospective contacts with industry, namely Intel (Europe) and National Semiconductors (NSC) for eventual technology transfer regarding our research results on multicore systems (Intel) and pre-competitive analysis for large-scale deployment of wireless sensor networks (NSC).

The strategy has been also to reinforce collaborations with the Portuguese industrial tissue, namely with some of the most predominant companies actuating in our areas. Companies such as Microsoft Portugal, Critical Software, MRA/CrossBow or EFACEC are following or even collaborating with us within some of our research areas.

In 2009, additional contacts were made with some Portuguese companies (namely PT, Novabase and Critical Materials) which successfully lead to the collaboration of joint project proposals to the PT-CMU program.

Contacts were also made with PT Inovação concerning direct research contracts. And together with Critical Software we have driven the project proposal and are now participating (WP4 leader) in the ARTEMIS project EMMON on large-scale embedded monitoring using WSNs.

Within the ongoing collaboration with Civil Engineers at ISISE (<http://www.isise.net>) devising a structural health monitoring system based on Wireless Sensor Networks, the group was contracted to design and develop a prototype system including several sensor boards (precision vibration, temperature, humidity), drivers and communication protocol [O20].

Recognizing the importance of this activity, in 2009 an area of responsibility in Industry Contracts and Intellectual Property issues was created within the Executive Board, with the goal to foster technology and knowledge transfer to industry through industry direct contracts.

### INTERNATIONALIZATION

While collaborations with Portuguese academic, research and industrial parties were not neglected, the group mostly plays at the international arena, collaborating with the most prestigious research groups in Europe and the U.S., and being regularly active in international events, standardization committees and organizations (e.g. the Euromicro Real-Time Systems Technical Committee, the IFIP WG10.2 on Embedded Systems, the Ada-Europe Board and the TinyOS 15.4 and ZigBee WGs).

We have published results together with international institutions, e.g. the University of Brussels, the Swedish Institute of Computer Science, Delft Technical University, NICTA, National University of Ireland, University of Pennsylvania, Korea Advanced Institute of Science and Technology and Boston Scientific Inc. [J3,J4,J5,O9,O11,O14,O16,O24].

During 2009 we integrated a consortium of 41 industrial/academic partners from 9 European countries in the ARTEMIS project RECOMP (led by Kone, Finland), and where the group will take a prominent role. We have co-driven another ARTEMIS project proposal titled PALAEMON with European Microsoft Innovation Center (EMIC), being the proposal ranked 16th from among 56. Also in 2009 we have started exploration of 3 potential projects for the 2010 Call for ARTEMIS projects.

We have been active in the ArtistDesign and CONET NoEs. In particular, in ArtistDesign we are actively (and increasingly) contributing to the "Design for Adaptivity" Inter Cluster activity, while in CONET we lead the COTS4QoS and SDP research clusters.

In the summer we hosted 6 students from well reputed Indian Universities. One of which has gained entry in the CMU-Portugal PhD program and will be co-supervised by group researchers, while another is under consideration for a PhD position in our group. We also added a number of PhD students in our team, including students from Cuba, India and Iran, being further internationalization of our PhD students currently in progress.

## RESEARCH PROJECTS

### EUROPEAN NETWORKS OF EXCELLENCE

#### ARTIST2



#### NETWORK OF EXCELLENCE ON EMBEDDED SYSTEM DESIGN

Project IST-004527, EU-funded  
CISTER funding: 150 KEUR

4 YEARS (OCT 2004 TO SEP 2008)

The objective of ARTIST2 is to strengthen European research in Embedded Systems Design, and promote the emergence of this new multi-disciplinary area. We gather together the best European teams from the composing disciplines, and will work to forge a scientific community.

#### CONET



#### COOPERATING OBJECTS NETWORK OF EXCELLENCE

Project FP7-ICT-224053, EU-funded  
CISTER funding: 250 KEUR

4 YEARS (JUN 2008 TO MAY 2012)

A number of different system concepts have gained a lot of relevance in the area of embedded systems over the past couple of years: Embedded systems, pervasive computing and wireless sensor networks. These three types of quite diverse systems share a lot of commonalities but also have some complementary aspects in common that make a combination into a coherent system vision promising.

The term "Cooperating Objects" was coined explicitly for the purpose of describing such systems by the Embedded WiSeNts Consortium, a Coordination Action funded by the EC in FP6. One of the main results was the publishing of the Embedded WiSeNts Research Roadmap that defines the concept of Cooperating Objects. The vision of Cooperating Objects is, therefore, quite new and needs to be understood in more detail and probably extended with inputs from the relevant individual communities that compose it. This will enable us to better understand the impact on the research landscape and to steer the available resources in a meaningful way.

The main goal of CONET is to build a strong community in the area of Cooperating Objects capable of conducting the needed research to achieve, in the long run, the vision of Mark Weiser.

## RESEARCH PROJECTS

### EMMON



#### EMBEDDED MONITORING

Project Artemis 100036

CISTER Funding: 250 KEUR

3 YEARS (SEP 2007 TO SEP 2010)

EMMON goal is to allow monitoring huge geographical extensions in real time, obtaining information from the field of observation as variations occur, using Wireless Sensor Network (WSN) devices – small communicating & cooperative nodes with sensors.

### PT-CMU



#### CMU PORTUGAL

CISTER Funding: 350 KEUR

6 YEARS (JAN 2007 TO DEC 2012)

The CMU-Portugal Program is a partnership between the Carnegie Mellon University (CMU, Pittsburgh, USA) and the Portuguese Government, aiming at creating top level and internationally recognized education and research programs in Information and Communication Technologies (ICT).

Within the CMU-Portugal Program, CISTER/IPP-HURRAY is involved in a collaborative scientific program that integrates the capabilities of the Carnegie Mellon University, in particular the Electrical and Computer Engineering Department and CenSCIR, and the following Portuguese research institutions: ISR-Lisbon and INESC-ID (affiliated with IST/UTL), CISTER/IPP-HURRAY (affiliated with ISEP/IPP) and the ISQ Group.

This collaborative scientific program includes a dual doctoral program in the area of Electrical and Computer Engineering. The main focus of this doctoral program is on Sensing Technologies and Networks for Risk Minimization Systems, with an additional emphasis on their application to Cyber-Physical Systems such as critical infrastructures. This wide area of research includes communication infrastructures (e.g., wireless sensor and ad-hoc networks), hardware/software platforms (embedded real-time and distributed computing systems), sensing and decision systems (signal/video processing, surveillance, robotics and distributed decision systems) and risk assessment.

Students will be supervised by two faculty advisors, one from Carnegie Mellon and the other from one of the Portuguese partners. The dual doctoral program is structured so that students spend part of their time at CMU and at one of the Portuguese partner Institutions.

This PhD is to be offered by the Department of Electrical and Computer Engineering at the Carnegie Mellon University (CMU), Pittsburgh, USA and by the Department of Electrical and Computer Engineering at Instituto Superior Técnico (IST), Universidade Técnica de Lisboa (UTL), Lisbon, Portugal.

This research partnership has been launched in Portugal between CISTER/IPP-HURRAY, ISR-Lisbon, INESC-ID and ISQ, but it is expected to bring together other leading Portuguese institutions. The following CMU Units are involved: Center for Sensed Critical Infrastructure Research (CenSCIR), Electrical and

Computer Engineering (ECE) Department, Computer Science (CS) Department, Engineering and Public Policy (EPP) Department, and Tepper, the CMU Business School.

## COOPERATES



### **QoS-AWARE COOPERATIVE EMBEDDED SYSTEMS**

PTDC/EIA/71624/2006

CISTER Funding: 80 KEUR

### 3 YEARS (SEP 2007 TO SEP 2010)

Quality of Service (QoS) is considered an important user demand, receiving wide attention in real-time research. However, in most systems, users do not have any real influence over the QoS they can obtain, since service characteristics are fixed when the systems are initiated.

Furthermore, applications (and their users) can differ enormously in their service requirements as well as in the resources which need to be available to them. These applications present increasingly complex demands on quality of service, reflected in multiple attributes over multiple quality dimensions.

At the same time, the use of embedded devices with wireless network interfaces is growing rapidly. The increasing pervasiveness of these devices in the everyday life is changing the way computing systems are used and interact, creating a new, highly dynamic and decentralized environment.

## RECOMP



### **REDUCED CERTIFICATION COSTS FOR TRUSTED MULTI-CORE PLATFORMS**

Artemis 100202

CISTER Funding: 456 KEUR

### 3 YEARS (APR 2010 TO MAR 2013)

RECOMP recognizes the fact that the increasing processing power of embedded systems is mainly provided by increasing the number of processing cores. The increased numbers of cores is commonly regarded as a design challenge in the safety-critical area, as there are no established approaches to achieve certification. At the same time there is an increased need for flexibility in the products in the safety-critical market. This need for flexibility puts new requirements on the customization and the upgradability of both the non-safety and safety-critical critical part. The difficulty with this is the large cost in both effort and money of the re-certification of the modified software, which means that companies cannot fully leverage the advantages of modular software system. RECOMP will provide reference designs and platform architectures together with the required design methods and tools for achieving cost-effective certification and re-certification of mixed-criticality, component based, multi-core systems. The

aim of RECOMP is to define a European standard reference technology for mixed-criticality multi-core systems supported by the European tool vendors participating in RECOMP.

Partners of the RECOMP consortium include, among others:



## REHEAT



### REAL-TIME SCHEDULING ON HETEROGENEOUS MULTICORE ARCHITECTURES

FCOMP-01-0124-FEDER-010045 PTDC/EIA-CCO/105716/2008  
CISTER Funding: 130 KEUR

3 YEARS (FEB 2010 TO JAN 2013)

Parallel processing platforms are spreading at an unprecedented rate. Traditionally, parallel processing platforms were used to reduce the execution time of a large computational job such as predicting the weather but now they are also used in low-end systems and embedded real-time systems thanks to the availability of multicore processors. And those systems are often comprised of a large number of independent tasks. Designers are well-aware that processing units specialized for a specific function can offer a significant performance boost. Consequently, heterogeneous multicores now enjoy a period of widespread use. Virtually all major semiconductor companies are offering or have declared plans to offer heterogeneous multicores.

This project aims to create provable good real-time scheduling algorithms for heterogeneous multicores.

## REJOIN



### REAL-TIME SCHEDULING ON MULTICORE PROCESSORS: ADDRESSING TWO OPEN PROBLEMS JOINTLY

FLAD / NSF 91-02/10  
CISTER Funding: 7 KEUR

11 MONTHS (JUN 2010 TO MAY 2011)

The objectives of this project is to study the following two problems:

- P1. Multiprocessor Global Feasibility Analysis - Arbitrary-Deadline Tasks;
- P2. Resource sharing on Multiprocessor Systems.

The main challenge with respect to P1 is that optimal scheduling for the problem P1 requires knowledge of future job arrivals. It has recently been shown [1] that no optimal solution exists for problem P1 even for the slightly more restricted model of sporadic tasks. Creating non-optimal algorithms is worthwhile though.

Problem P2 is non-trivial because normal uniprocessor solutions, Priority-Inheritance Protocol (PIP) and Priority Ceiling Protocol (PCP), perform poorly. The former (PIP) allows a large degree of parallel execution but there are many situations when a lower priority task inherits a much higher priority and this can happen multiple times and this cause delays to a medium priority task. The latter (PCP) severely limits parallel execution. Because of the poor performance PIP and PCP, new solutions to P2 must be devised.

## RESCORE



### REAL-TIME SCHEDULING ON MULTICORES

PTDC/EIA/78141/2006

CISTER Funding: 156 KEUR

#### 3 YEARS (SEP 2007 TO SEP 2010)

Multiprocessors have already made the transition from high-end computing to desktops and laptops. This was possible because of the miniaturization of integrated electronics system which allowed the implementation of multiprocessors on a single chip, called multicores.

Now, the next step is about to begin. These multicores are targeting embedded real-time systems as witnessed by (i) the commercial availability of multicore PowerPC and ARM processors and (ii) Intel's and AMD's recent marketing of the use of multicores in embedded systems. Today, more than 99% of all computers are embedded systems. These computers operate within products to improve their functionality.

Often human beings are not aware of the existence of these computers - as long as they are working as intended. Pace makers, cars, electronic pianos, vacuum cleaners and walking robots, all represent examples of embedded computers. In fact, virtually every product developed in the future will host an embedded computer. For this reason, they constitute an enabling technology for most goals in our life, our society and the economy.

## RESCUE



### RELIABLE AND SAFE CODE EXECUTION FOR EMBEDDED SYSTEMS

PTDC/EIA/65862/2006

CISTER Funding: 80 KEUR

#### 3 YEARS (SEP 2007 TO SEP 2010)

This project looks at an important requirement in safety critical systems -- that of supporting verifiability of software components. The project partners focus on embedded systems, thereby making the approach more manageable. This also provides a more significant challenge, in that the device in which the verification is being undertaken is resource constrained. The approach is clearly applicable to a variety of different contexts and scenarios.

The use of certificates in Proof Carrying Codes provides a useful basis to support such verifiability provides a useful first step for the research being proposed here. The authors advocate the use of: (i) Type-based; (ii) Language-based; and (iii) Logic-based security enforcement mechanisms.

## REWIN



### REAL-TIME GUARANTEES IN WIRELESS SENSOR NETWORKS

FCOMP-01-0124-FEDER-010050 PTDC/EIA-CCO/109027/2008

CISTER Funding: 68 KEUR

#### 3 YEARS (FEB 2010 TO JAN 2013)

A class of WSN applications require timely response to events. For example, in a smart nursing home WSN scenario, it is necessary to guarantee that life-threatening events such as heart-attacks are communicated to doctors within a bounded time. The ability to support real-time applications is fundamental to the advancement of capabilities of WSN, and is the motivation for this proposed research. Since communication is an integral part of WSN, the performance of WSN is mainly determined by the quality and capacity of the wireless channel. The limited previous research that exists is insufficient to guarantee (with mathematical proofs) a low delay for disseminating the occurrence of rare but critical events, such as the heart-attack mentioned above. This project, we will develop methods to offer hard real-time guarantees to individual real-time flows over multi-hop WSN of arbitrary node deployments and arbitrary traffic pattern. These methods will guarantee a small delay for disseminating the occurrence of critical events.

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[T2] Barros, A., "Timing Analysis of an Embedded Architecture for a Real-Time Power Line Communications Network", MSc Thesis, Faculdade de Engenharia da Universidade do Porto, Porto, Portugal, March 2009.

[T3] Batsa, M. "Supporting Different QoS Levels in Multiple-Cluster Wireless Sensor Networks", MSc Thesis, Department of Electronics and Computer Engineering, Indian Institute of Technology (IIT) Roorkee, India, September 2009 (defended January 2010).

[T4] Nogueira, L., "Time-Bounded Adaptive Quality of Service Management for Cooperative Embedded Real-Time Systems", PhD Thesis, Faculdade de Ciências da Universidade do Porto, Porto, Portugal, October 2009.

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[J2] Koubaa, A., Severino, R., Alves, M., Tovar, E., "Improving Quality-of-Service in Wireless Sensor Networks by mitigating hidden-node collisions", IEEE Transactions on Industrial Informatics, Special Issue on Real-Time and Embedded Networked Systems, Vol. 5, Issue 3, August 2009, pp. 299 - 313.

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- [O4] Andersson, B., Pereira, N., Tovar, E., Gomes, R., "Using a Prioritized Medium Access Control Protocol for Incrementally Obtaining an Interpolation of Sensor Readings", 7th Work. on Intelligent Solutions in Embedded Systems (WISES'09), Ancona, IT, June 2009, pp. 29-36
- [O5] Koubaa, A., Andersson, B., "A Vision of Cyber-Physical Internet", 8th International Work. on Real-Time Networks (RTN'09), Dublin, IR, July 2009
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[O23] Pereira, N., Andersson, B., Tovar, E., Carvalho, P., "Efficient Computation of MIN and MAX in Multihop Networks (by exploiting a prioritized MAC protocol)", Lecture Notes in Electrical Engineering, Vol. 38, Intelligent Technical Systems, 2009, pp. 233-246

[O24] Easwaran, A., Lee, I., Sokolsky, O., Anand, M., Phan, T.X.L., "Simulation Relations, Interface Complexity, and Resource Optimality for Real-Time Hierarchical Systems", Work. on Reconciling Performance with Predictability (RePP), Embedded Systems Week 2009

## PATENTS/PROTOTYPES

During 2009 group researchers have filed the following patents:

US Provisional Patent Application No. 61/176,549: B. Andersson, N. Pereira, E. Tovar and R. Gomes, "Using a Prioritized Medium Access Control Protocol for Incrementally Obtaining an Interpolation of Sensor Readings", May 2009.

US Provisional Patent Application No. 61/255,611: L. Nogueira, L. M. Pinho, "Time-Bounded System for Managing Quality of Service in Open Embedded Real-Time Systems", October 2009.

Concerning prototypes, the open-ZB open-source toolset for the IEEE 802.15.4 and ZigBee protocols is available at <http://www.open-zb.net>. This site already witnessed over 85000 visits and 6000 downloads (average 4-5 downloads per day) of the toolset, from tens of world-reputed universities and companies.

In 2009, a framework between the group and ISISE (<http://www.isise.net>) has been settled for devising a structural health monitoring system based on WSN. A prototype system has been designed, implemented and validated, being composed of several COTS WSN nodes integrated with group-designed sensor boards, drivers and communication protocols [O20].

In a joint effort with researchers at ReDCAD (Tunisia), UFCS (Brazil) and DERI-NUIG (Ireland), we have been driving cutting edge R&D on radio link quality estimation (LQE) in WSNs, a basic building block for supporting higher level protocols and mechanisms such as routing, mobility management, fault-tolerance,

deployment, topology control. We have been devising RadiaLE - a benchmarking test-bed for the performance evaluation of LQEs, available as an open-source (<http://www.open-LQE.net>) and innovative link quality estimators based on Fuzzy Logic that show significant benefits over existing ones [O14].

Further, in collaboration with the University of Pennsylvania (USA), one of our researchers has developed a new tool called Compositional Analysis of Real-Time Systems (CARTS), available on the public forum as an open-source entity (<http://rtg.cis.upenn.edu/carts/>).