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

Annual Report
2008

CONTENTS

EXECUTIVE SUMMARY

The Research Centre in Real-Time and Embedded Computing Systems (CISTER) 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 2004, CISTER was granted the classification of 'Excellent' from an international jury. We firmly believe that ever since then, and particularly during 2007, we have been exceeding the expectations placed on us.

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, an Adjunct Director, a Scientific Board and an Advisory Committee. 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 early report (scientific and financial) to the Scientific Board. The main responsibilities of the Adjunct Director are to assist and replace the Director when necessary. The Scientific Board, which includes all the members of the Unit with PhD degree, has the following main responsibilities: to appoint the Director and Adjunct Director; to define the scientific research areas and working strategies; to carry out research; and to approve the plan of activities, budget and early report.

The activities of CISTER are periodically reviewed by Advisory Committee (AC) members. Annually, a number of on-site visits are performed by top-ranked 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 2008, the CISTER research team was composed by:

- Number of Researchers holding a PhD: 10
- Number of Researchers holding a MSc: 8

In 2008 the unit had around 586K EUR of competitive funding. During 2008 CISTER had 4 international and industrial driven projects, and 3 fundamental research projects (FCT supported) running.

In 2008 CISTER got approved a set of new projects, accounting for a budget of 144K EUR in the year, with a total budget of 526K 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. This implies that, unlike more traditional information and communication systems, where there is a separation between correctness and performance, in RTS correctness and performance are very tightly interrelated.

Historically, RTS were an important, but narrow, niche of computer systems, consisting mainly of military systems, air traffic control and embedded systems for manufacturing and process control. This association caused that RTS problems did not attract widespread interest from the computer community. Meanwhile, the emergence of largescale distributed systems, enabled by advances in networking technology, has broaden real-time concerns into a mainstream enterprise, with clients in a wide variety of industries and academic disciplines. This tendency has been establishing RTS technology as a priority for commercial strategy and academic research for the foreseeable future and also for a wider number of applications.

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. These include not only the most prestigious research groups in Europe (York, UK; SSSUP, Italy; MdH, Sweden; TUW, Austria) as well as a large number of research groups in the U.S., such as those from the UNC-CH, the UIUC, the UVa, the WUStL or the CMU, to mention just a few. This is just a sample of prestigious research/higher education 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. Even given our relatively small dimension, we have been able to compete internationally with cutting-edge and seminal research into a few, but strategically defined, research topics. And we have been tremendously successful.

Therefore, the general objectives of CISTER consists on developing cutting-edge research on real-time computing systems. The focus is on fundamental research issues, including PhD and MSc research works. But the Unit also cares on drawing the obtained cutting-edge results into applied research driven in the framework of international academic/industrial partnerships.

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.

CISTER competes internationally with cutting-edge and seminal research into a few, but strategically defined, research topics, achieving outstanding results, as outlined in the next section

MAIN ACHIEVEMENTS

CISTER has been assuming international leadership in the support of Quality-of-Service (QoS) in WSNs, through both standard and commercial technology and cutting-edge solutions designed from scratch. CISTER researchers are world leaders on IEEE 802.15.4 and ZigBee technologies, providing methodologies and tools to analyse, dimension and engineer WSNs with improved QoS (open-ZB toolset – over 70000 visits and 5000 downloads) [J1, J2, T1, O13].

WiDOM is a wireless dominance-based MAC protocol (like the one used in the Controller Area Network) proposed by CISTER researchers. It provides unprecedented advantages for WSNs, since aggregate computations (data aggregation, interpolation) can be performed with a time complexity that is independent of the number of sensing nodes, greatly leveraging scalability [J3, J4, T2, O7-O9].

CISTER, together with Critical Software, has driven the project proposal (during 2008) and is now participating (WP4 “communication & protocols” leader) in the Artemis project EMMON on large-scale embedded monitoring using WSNs. CISTER was also in the genesis and is one of the core partners in the European NoE on Cooperating Objects (CONET), leading WP5 “Spreading of Excellence” and two research clusters (SDP and COTS4QoS) and participating in other three research clusters (TSPCO, RMA and UICO). As part of the Spreading of Excellence work-package, CISTER coordinated the MSc/PhD Thesis award awarded at EWSN’09 (February 2009).

International leadership and recognition in the WSN area is also illustrated by: the organization the 7th Int. Workshop on Real Time Networks (RTN'08, collocated with 20th ECRTS) and the Int. Workshop on Cyber-Physical Systems Challenges and Applications (CPS-CA’08, collocated with 4th DCOSS’08); EWSN 2009 Best Master Thesis Award [T1] (defended in October 2008); two Seminars in a doctoral school, L'Aquila, Italy, September 2008. A key researcher of CISTER was also keynote speaker at the 16th RTNS 2008, with a talk entitled “Highly Scalable Aggregate Computations in Cyber-Physical Systems: Physical Environment Meets Communication Protocols”

CISTER is among the best 5 groups in the world (strongest in Europe) in the area of RT Multiprocessor Systems. Just an example, we created the first multiprocessor real-time scheduling algorithm with few preemptions and that can assure that at least 50% of the processing capacity can be requested for sporadic tasks without missing a deadline. (In 2006 we did so for periodic tasks, a special case.) In this domain, the RESCORE FCT project, led by CISTER is being of paramount importance to leverage this scientific area. Publications [O1-O6] are elucidative of the international impact and recognition of our work in this area.

Concerning QoS-Aware computing, runtime adaptation is a fundamental issue in resource-constrained QoS-aware systems since it determines how well users' service requests are satisfied in the presence of dynamically changing operating conditions. We proposed a QoS adaptation mechanism that allows users to control the runtime adaptation behaviour of their applications [O10], even when considering inter-dependent adaptations that span multiple inter-dependent components [O11]. Furthermore, we have proposed a novel scheduling strategy for supporting possibly inter-dependent task sets that share resources and exhibit precedence constraints among them [O12]. FCT funded projects CooperatES and RESCUE have been very important within this context.

CISTER’s PhD researchers participated in 2008 as PC Chairs, PC members, Track Chairs in the most reputed scientific events the concerned research areas. Another researcher is since June 2007 Editor-in-chief of the Ada User Journal.

ACTIVITIES

INTEGRATIVE/MULTIDISCIPLINARY ACTIVITIES

Although the relatively small dimension of the unit, its areas of research are by their nature multidisciplinary. The unit has fostered the integration of researchers from different background areas with the goal of setting up a team with complementary, but nevertheless focused, competences.

Of particular relevancy, was the strategy to involve researchers from different institutions and countries, with different yet complementary experience, allowing attaining a comprehensive spectrum of knowledge. This policy was strictly continued and amplified during 2008. CISTER includes researchers with diverse academic backgrounds, such as Electrical and Computer Engineering, Informatics Engineering, Computer Science and Applied Physics/Mathematics

These complementary competences allowed increasing the research 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.

This has been enabling the research unit to lead international research in embedded computing systems, including the emerging Cyber-Physical Systems (CPS). Although the IT transformation in the 20th century appeared revolutionary, a bigger change is yet to come, exemplified by the emerging cyber-physical computer systems (CPS). In those, the computer systems do not only compute abstract quantities; they 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, and given that the computing entities interact with their environment, the timeliness is of increasing importance. Integration of physical processes and computing is not new. Embedded systems have been since a long time in place to denote systems that combine physical processes with computing. The revolution will come from massively networking embedded computing devices. Such extreme networking poses considerable technical challenges ranging from the (distributed) programming paradigms (languages still lacking temporal semantics, suitable concurrency models and hardware abstractions) to networking protocols with timeliness as a structuring concern, and including systems theory that combines "physical concerns" (control systems, signal processing, etc.) and "computational concerns" (complexity, schedulability, computability, etc.).

The research unit is involved in a number of national and international projects that are multi-site and multi-disciplinary.

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 organized 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.

In this sense, most of our fundamental research activities are supported by applied research vertices. We are aware that CISTER scientific results are much better assimilated by the general public through practical demonstrations with state-of-the-art technology and appealing (yet realistic) application scenarios. This

approach has been common practice in the Unit (e.g. RFieldbus manufacturing automation field-trial, http://www.cister.isep.ipp.pt/rfpilot), and was also instantiated during 2008 with several demonstration testbeds on wireless sensor networks (e.g. ART-WiSe search&rescue testbed - http://www.cister.isep.ipp.pt/ART-WiSe/testbed.php). These real application demonstrators have proven to shorten the gap between industrials (and even the general public) and the research community.

CISTER 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 lines.

Notably, CISTER, together with Critical Software, has driven the project proposal (during 2008) and is now participating (WP4 leader) in the Artemis project EMMON on large-scale embedded monitoring using WSNs. Internationally, SAP, Schneider Electric, and Telecom Italia are participating with us in competitive third-party-funded research projects such as CONET.

We have also been very successful in engaging students with our research activities. That is the case of the BII grants we have been granting since 2008.

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.

In 2008, several senior researchers of the unit were PC Members of world-reputed events such as IEEE RTSS, ECRTS, IEEE RTAS, IEEE RTCSA, WPDRTS, IEEE SRDS, IEEE ICDCS, ACM EMSOFT, OPODIS, Ada-Europe, IFIP DIPES, ACM SAC, IRTAW, IEEE ETFA, IEEE WFCS, IFAC FET.

Importantly, one CISTER researcher were program chairs for both the 7th International Workshop on Real-Time Networks (RTN 2008 – www.cister.isep.ipp.pt/rtn08) and the 1st International Workshop on Cyber-Physical Systems, Challenges and Applications (CPS-CA 2008 – www.cister.isep.ipp.pt/cps-ca08)

INDUSTRY CONTRACT RESEARCH

In the context of industry-driven research, the Unit has been steadily increasing its efforts to integrate research results in existent and new technologies.

The investment the Unit has recently been performing in specific areas such as Wireless Sensor Networks, has been important in attracting attention from industry which have demonstrated interest in fostering the research and jointly provide new and improved solutions in the area.

In this context, several initiatives have been triggered in 2007, leading to collaborations with companies such as Critical Software (Portugal), ATMEL (Norway), among others.

There were a number of contacts and meetings in the framework of the critical infrastructures and risk assessment consortium of the PT-CMU program with key Portuguese end user companies and technology providers. It is foreseen that these efforts will lead to industry-funded research contracts as well.

INTERNATIONALIZATION

While bilateral and multilateral collaborations with Portuguese academic, research and industrial parties were not neglected, CISTER mostly plays at the international arena, collaborating with top level institutions on several strategic topics and at different levels.

As already referred, CISTER has been collaborating with the most prestigious research groups in Europe (e.g. York, UK; SSSUP, Italy; MdH, Sweden; TUW, Austria) and in the U.S. (e.g. UNC-CH, UIUC, UVa, WUStL, CMU, USC).

In 2008, CISTER was deeply involved in triggering industry-driven EU project proposals, involving reputed companies such as Critical Software, Siemens, Schneider, Intel and SAP. The Unit has also been actively participating in the ArtistDesign NoE. CISTER, has co-driven the project proposal (during 2008) with Critical Software and is now participating in the Artemis project EMMON. CISTER was also in the genesis and is one of the core partners in the CONET NoE.

CISTER PhD researchers have been consecutively participating in the most reputed international scientific events, as PC Chairs, General Chairs, PC members, Track Chairs, WiP Chairs, Industry Chairs or Publicity Chairs. We highlight the 2008 edition of the following series of top-ranked scientific events.

Importantly, one CISTER researcher were program chairs for both the 7th International Workshop on Real-Time Networks (RTN 2008 – www.cister.isep.ipp.pt/rtn08) and the 1st International Workshop on Cyber-Physical Systems, Challenges and Applications (CPS-CA 2008 – www.cister.isep.ipp.pt/cps-ca08)

CISTER researchers were invited to and actively participating in standardization committees and international organizations, e.g. the Euromicro Real-Time Systems Technical Committee, the IFIP WG10.2 on Embedded Systems, the board of the Ada-Europe Organization and the TinyOS 15.4 and ZigBee WGs.

The research excellence attained by the Unit has been leveraging the invitation to join several consortiums for driving new long-term research initiatives. Since 2006, we have engaged a long-term research framework with the CMU, under the CMU-Portugal program.

Some of our ongoing collaborations lead to joint publications with researchers from the North Carolina University at Chapel Hill ([O4]), TU Vienna [J3] and Czech Technical University [O13].

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.

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.

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.

REFLECT

Reflection Mechanisms in Real-time Embedded Systems

PTDC/EIA/60797/2004
CISTER Funding: 50 KEUR

30 months (Jan 2005 to Oct 2007)

The main goal of this project is to provide real-time systems with a generic framework for dynamic application monitoring and control, which uses the advantages offered by advanced programming paradigms, with a particular focus on reflection technologies. The correct use of this technology will allow building systems where the functional aspects are guaranteed to be reliable and deterministic, whilst providing the required flexibility.

The main target of this framework is to support online resource consumption feedback for systems with dynamic QoS requirements.

PUBLICATIONS

THESIS

[T1] Ricardo Severino, "On the use of IEEE 802.15.4/ZigBee for Time-Sensitive Wireless Sensor Network Applications", Master Thesis in ECE, Polytechnic Institute of Porto, School of Engineering, October 2008. This Thesis received the BEST EWSN/CONET MSc THESIS AWARD, Cork, Ireland, February 2009.

[T2] Ricardo Gomes, "Efficient Implementation of a Dominance Protocol for Wireless Medium Access", Master Thesis in ECE, Polytechnic Institute of Porto, School of Engineering, November 2008.

JOURNAL PAPERS

[J1] A. Koubâa, M. Alves, E. Tovar, A. Cunha, "An implicit GTS allocation mechanism in IEEE 802.15.4 for time-sensitive wireless sensor networks: theory and practice", Published in Springer Real-Time Systems Journal, Volume 39, Numbers 1-3, pp 169 - 204, Springer, August 2008.

[J2] A. Koubâa, A. Cunha, M. Alves, E. Tovar, "TDBS: A Time Division Beacon Scheduling Mechanism for ZigBee Cluster-Tree Wireless Sensor Networks", Real-Time Systems Journal, Springer, Volume 40, Number 3, December 2008, pp. 321-354.

[J3] B. Andersson, N. Pereira, W. Elmenreich, E. Tovar, F. Pacheco, N. Cruz, "A Scalable and Efficient Approach to Obtain Measurements in CAN-based Control Systems", Published in IEEE Transactions on Industrial Informatics (TII), Volume 4, Issue 2, May 2008, pages 80-91.

[J4] B. Andersson, N. Pereira, E. Tovar, "Analysing TDMA with Slot Skipping", Published in IEEE Transactions on Industrial Informatics (TII), Volume 4, Number 4, pp. 225-236, November 2008.

OTHER PUBLICATIONS

[O1] B. Andersson, “The Utilization Bound of Uniprocessor Preemptive Slack-Monotonic Scheduling is 50%,'' in Proceedings of the 23rd ACM Symposium on Applied Computing (SAC’08), Fortaleza, Ceara, Brazil, March 16--20, 2008.

[O2] B. Andersson, “Schedulability Analysis of Generalized Multiframe Traffic on Multihop-Networks Comprising Software-Implemented Ethernet-Switches'', in Proceedings of IEEE International Workshop on Parallel and Distributed Real-Time Systems (WPDRTS’08), Miami, Florida, April 14-18, 2008. Organized in conjunction with IPDPS´08.

[O3] B. Andersson and K. Bletsas, “Sporadic Multiprocessor Scheduling with Few Preemptions'', in Proceedings of 20th Euromicro Conference on Real-Time Systems (ECRTS’08), Prague, Czech Republic, July 2-4, 2008.

[O4] B. Andersson, K. Bletsas and S. K. Baruah, ''Scheduling Arbitrary-Deadline Sporadic Tasks on Multiprocessors,'' in Proceedings of the 29th IEEE Real-Time Systems Symposium, Barcelona (RTSS’08), Spain, November 30-December 3, 2008.

[O5] B. Andersson, ''Global Static-Priority Preemptive Multiprocessor Scheduling with Utilization Bound 38%,'' in Proceedings of the 12th International Conference On Principles of Distributed Systems (OPODIS’08), Luxor, Egypt, December 15--18, 2008. Also, published as LNCS 5401.

[O6] B. Andersson, ''Uniprocessor EDF Scheduling with Mode Change,'' in Proceedings of the 12th International Conference On Principles of Distributed Systems (OPODIS’08), Luxor, Egypt, December 15--18, 2008. Also, published as LNCS 5401.

[O7] B. Andersson and S. Prabh, “Localizing an Object in Large-Scale Cyber-Physical Systems'', in International Workshop on Cyber-Physical Systems Challenges and Applications (CPS-CA'08), Santorini Island, Greece, June 11, 2008, in conjunction with the 4th IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS'08), Invited paper.

[O8] B. Andersson, N. Pereira and E. Tovar, ``How a Cyber-Physical System Can Efficiently Obtain a Snapshot of Physical Information Even in the Presence of Sensor Faults'', in Proceedings of Sixth Workshop on Intelligent Solutions in Embedded Systems (WISES'08), Regensburg, Germany, July 10-11, 2008.

[O9] E. Tovar, B. Andersson, N. Pereira, M. Alves, S. Prabh, F. Pacheco, "Highly Scalable Aggregate Computations in Cyber-Physical Systems: Physical Environment Meets Communication Protocols", Proceedings of the 7th International Workshop on Real-Time Networks (RTN'08), Prague, Czech Republic, July 1, 2008. In conjunction with ECRTS’08.

[O10] Nogueira, L., Pinho, L., "Dynamic QoS Adaptation of Inter-Dependent Task Sets in Cooperative Embedded Systems", Published in Proceedings of the 2nd ACM International Conference on Autonomic Computing and Communication Systems, Turin, Italy, September 2008.

[O11] Nogueira, L., Pinho, L., "Handling QoS Dependencies in Distributed Cooperative Real-Time Systems", Published in Proceedings of the 6th IFIP Working Conference on Distributed and Parallel Embedded Systems, Milan, Italy, September 2008.

[O12] Nogueira, L., Pinho, L., "Shared Resources and Precedence Constraints with Capacity Sharing and Stealing", Published in Proceedings of the 22nd IEEE International Parallel and Distributed Processing Symposium, April 14-18, Miami, Florida, USA.

[O13] Jurcik P., Severino R., Koubaa A., Alves M., Tovar E., "Real-Time Communications over Cluster-Tree Sensor Networks with Mobile Sink Behaviour”, 14th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA 2008), Kaohsiung, Taiwan, 25-27, August, 2008.

PATENTS/PROTOTYPES

US Patent: B. Andersson and J. Lext, “Calculating Packet Delay in a Multihop Ethernet Network'', Application date: April 2008. patent pending.

The open-ZB open-source toolset for the IEEE 802.15.4 and ZigBee protocols is available at http://www.open-zb.net. This toolset features: (i) implementation of the IEEE 802.15.4 protocol in TinyOS, for both the MICAz and TelosB motes; (ii) implementation of the ZigBee Network Layer for supporting synchronized multiple cluster topologies in TinyOS, for the TelosB motes; (iii) a simulation model of the IEEE 802.15.4 protocol in OPNET; (iv) software tools (based on MATLAB and MS Excel) for timing analysis and network dimensioning. This site already witnessed 70000 visits (effective visits, not just mouse clicks) and over 5000 downloads of the toolset, from top universities (e.g. UCB, UCLA, USC, UPurdue, UHarvard, MIT, CMU, UTAustin, ETHZ, KTH, TUDelft, EPFL, TUVienna, TUBerlin, TCDublin, LORIA) and companies (e.g. Honeywell, Ericsson, Microsoft, ABB, Alcatel-Lucent, Sharp, Philips, NEC ST, STMicroelectronics, Infineon, ubisys, Telecom-ParisTech, CEA, LG CNS, NXP, Samsung, Aerospace Corp., Selex Communications, SAAB, Atmel, CrossBow, MeshNetics). The open-ZB IEEE 802.15.4/ZigBee protocols implementation in TinyOS triggered the collaboration with the TinyOS Network Protocol Working Group. The importance of this work has been recognized by the TinyOS Alliance, leading to the creation of the TinyOS 15.4 and ZigBee Working Groups.

Within the WiDOM framework, several prototypes and tools have been provided, such as: (i) a nano-RK implementation of WiDOM for the MICAz and FireFly motes; (ii) a TinyOS implementation of WiDOM for the MICAz motes; (iii) a simulation model of WiDom for Multiple Broadcast Domains (MBD) in the

OMNet++ simulator; (iv) a simulation model to compute an estimation of the number of nodes, designed to exploit WiDOM.

RESEARCH GROUP – FUTURE RESEARCH

Since it was created, the research group grown to become one of the leading European research groups in the area, contributing with seminal research works in a number of subjects, such as: real-time communication networks and protocols; wireless sensor networks (WSN); real-time programming paradigms and operating systems; distributed embedded real-time systems; cooperative computing and QoS-aware applications; scheduling and schedulability analysis (including multiprocessor systems); cyber-physical systems (CPS).

This is a sufficiently broad spectrum of strategic research topics, which we will keep pursuing in the coming years. Research will therefore be organized around four main research lines:

- Wireless Sensor Networks
- Multicore Systems
- Cyber-Physical Systems
- Adaptive Real-Time Systems

WIRELESS SENSOR NETWORKS

The use of wireless communication networks has undergone a revolution during recent years, in application areas such as factory automation, home automation, vehicle-to-vehicle communications and Wireless Sensor Networks (WSN). The eagerness to introduce wireless communication everywhere has created a number of research challenges that researchers at CISTER/IPP-HURRAY are addressing from complementary perspectives: (i) the use of commercially available technologies versus the use of new protocols and solutions not considered by existing standards; (ii) the use of time-triggered paradigms versus event-triggered paradigms; (iii) the provision of short-term solutions recognizing the needs of companies for wireless solutions with mature implementations and compliant with standards in order to simplify interoperability versus the need to push the state-of-art and explore new innovative solutions.

Related to this research area, researchers at CISTER/IPP-HURRAY are participating in the Artemis (a European public/private research partnership) project EMMON (EMbedded MONitoring). CISTER/IPP-HURRAY is also one of the core partners in the European Network of Excellence on Cooperating Objects (CONET). Under CONET CISTER/IPP-HURRAY is leading two research clusters: COTS4QoS and SDP, and participates in two other: RMA and UICO.

MULTICORE SYSTEMS

Researchers at CISTER/IPP-HURRAY are currently developing scheduling algorithms and proof techniques which make it possible to prove at design time that deadlines will be met at run-time. While real-time scheduling on a single processor has enjoyed great successes during the recent four decades, such results are not available for the computer platform that matters the most today: the multiprocessor implemented on a single chip, also called multicore. Therefore, researchers at CISTER are working on the development of those results.

CISTER/IPP-HURRAY is one of the core partners in the European network of Excellence ARTISTDesign and has been granted one of the largest funding in the area of Electrical Engineering and Computer Science from the Portuguese Science Council (FCT) for our project RESCORE.

CYBER-PHYSICAL SYSTEMS

The extensive deployment of networked embedded computing devices in a blend that involves sensing, actuation, computation, networking, pervasiveness and physical processes poses considerable technical challenges ranging from the (distributed) programming paradigms (languages still lacking temporal

semantics, suitable concurrency models and hardware abstractions) to networking protocols with timeliness as a structuring concern, and including systems theory that combines "physical concerns" (control systems, signal processing, etc.) and "computational concerns" (complexity, schedulability, computability, etc.).

One of our main running efforts is related to solve the problem of performing scalable and efficient information processing in large-scale and dense cyber-physical systems. We are developing novel mechanisms under an approach of co-designing distributed algorithms for sensor data processing and underlying networked distributed computing systems with corresponding resource management schemes such that the utilization of resources is low.

Researchers at CISTER/IPP-HURRAY were invited to give the keynote talks about these recent developments and these research efforts are integrated in the research being developed under the European Network of Excellence on Cooperating Objects (CONET). Additionally, this research is related to our participation in the CIRA (Critical Infrastructures and Risk Assessment) initiative of the Portugal-CMU partnership.

ADAPTIVE REAL-TIME SYSTEMS

Within this research area, we address the issues associated with systems requiring temporal isolation of system parts with different criticality, as well as systems being robust and reliable in the context of additional restrictions like available energy, changing environment or a dynamic set of tasks executed on such a system. We have been developing new scheduling algorithms that consider the coexistence of the traditional isolated servers with a novel non-isolated type of servers, combining an efficient reclamation of residual capacities with a controlled isolation loss.

Researchers at CISTER/IPP-HURRAY are reformulating the distributed resource allocation problem as an anytime optimization problem in which there are a range of acceptable solutions with varying qualities, adapting the distributed service allocation is to the available deliberation time that is dynamically imposed as a result of emerging environmental conditions.

Finally, given the heterogeneity of services to be executed, users' quality preferences, underlying operating systems, networks, devices, and the dynamics of their resource usages, developing adaptive distributed embedded systems presents a number of challenges such as (i) designing a common understanding of how QoS should be specified; (ii) the provisioning of self-management actions that allow nodes to adapt to observed changes in the environment; (iii) resource management and scheduling strategies; and (iv) the design of an efficient coordination model that regulates individual autonomous adaptive actions.

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