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INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team TRIO

Temps Réel et InterOpérabilité (Real Time and InterOperability)

Nancy - Grand Est

THEME COM

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1. Team

Research Scientist

Liliana Cucu [Research Scientist, INRIA]
Nicolas Navet [Research Scientist, INRIA]

Faculty Member

Françoise Simonot-Lion [Team Leader, Professor, INPL, École Nationale Supérieure des Mines de Nancy, HdR]
Liliana Cucu [Teaching Assistant till August 2008, INPL]
Mathieu Grenier [Teaching Assistant till August 2008, Université Nancy 2]

External Collaborator

René Schott [Professor, UHP Nancy I, IECN]
François Simonot [Assistant Professor, UHP Nancy I, IECN]

Technical Staff

Xavier Grandmougin
Lionel Havet
Shanawaz Syed

PhD Student

Najet Boughanmi [Co-supervised with CRAN-Nancy, MNRT grant since September 2006]
Pierre Caserta [MNRT grant since October 2008]
Flavia Felicioni [Co-Supervised with Rosario University - Argentina, since September 2005]
Maha Idrissi Aouad [financed by contracts since October 2007]
Ning Jia [financed by contracts]
Dawood Khan [CORDI grant since September 2008]
Yanjun Li [co-supervised with Zhejiang university - China, as part of Franco-Chinese doctorial college program, since February 2007]
Aurélien Monot [CIFRE grant with PSA company since October 2008]
Bilel Nefzi [MESR grant since September 2007]
Shahram Nourizadeh [CIFRE grant with Medetic company since September 2007]
Jamila Ben Slimane [co-supervised with SUPCOM Tunis - Tunisia, since October 2007]

Post-Doctoral Fellow

Hugo Cruz Sanchez [INPL, since October 2008]

Visiting Scientist

Mounir Frikha [December 2008, as part of the INRIA-Tunisia program STIC07/I08]
Jian Hu [January-December 2008, University of Wuhan, China]
Stefan Petters [October 2008, Senior Researcher at NICTA, Australia]
Nabil Tabbane [December 2008, as part of the INRIA-Tunisia program STIC07/I08]
Zhi Wang [January-February 2008, Professor at Zhejiang University, China]

Administrative Assistant

Laurence Benini
Françoise Laurent

2. Overall Objectives

2.1. Highlights of the year

- The experience gathered over the years by the TRIO team in the field of technology transfer has lead to the creation of the startup RTaW (RealTime-at-Work) by Nicolas Navet and Lionel Havet. This startup offers services and software tools for the design of safe and resource-conscious electronic architectures embedded in transportation systems.
- Nicolas Navet and Françoise Simonot-Lion are editors of the CRC Handbook on "Automotive Embedded Systems"(December 4, 2008, 488 pages).

2.2. Objectives of the team

The goal of the TRIO team is to provide a set of techniques and methods that can be applied to design, validate and scale real time distributed applications. In order to tackle this problem as a whole, our work is structured along two complementary points of view:

- specification of real time on line mechanisms (protocols, schedulers, middleware) offering services to the application with a quality of service that ensures the satisfaction of real time constraints; this includes fault detection, fault recovery and fault tolerance,
- modeling, analysis and evaluation of real time distributed systems for the verification of temporal properties and the optimisation of distributed deployment.

Furthermore, we will continue to study the modeling process of real time distributed applications that allows the description of both functional and non-functional aspects of these applications and therefore a formal use of these models for quantitative evaluation and optimal scaling.

The problems to solve are mainly due to three particularities of targeted applications:

- They are discrete event systems with temporal characteristics (temporal performances of hardware support, temporal properties); this increases the complexity of their modeling and of their analysis. Hence a part of our research objectives is to master this complexity while stating a compromise between the accuracy of a model and its ability to be analyzed.
- A second aspect is the environment of these systems that can be the cause of perturbations. We need to take into account the impact of an uncertain environment (for example, the impact of electromagnetic perturbations on a hardware support) on the required properties. Therefore we have to develop stochastic approaches.
- Finally, the main characteristic of our works is based on the fact that we consider the performances of hardware supports. Consequently, the time that we manipulate is a physical (continuous) time and the studied systems are event driven timed systems.

These above mentioned main directions contribute to cover the full spectrum from formal modeling and evaluation of real time distributed systems up to their use in industrial problems, in particular, in the field of in-car electronic embedded systems or real time Quality of Service. Furthermore, some of our results yield to software tools and fruitful collaborations with the automotive industry.

3. Scientific Foundations

3.1. Scientific Foundations

In order to check for the timed behavior and the reliability of distributed systems, the TRIO team developped several techniques based on deterministic approaches ; in particular, we apply and extend analytical evaluation of worst case response time and when necessary, e.g. for open communication systems as internet based applications, we use techniques based on network calculus.

When the environment might lead to hazards (e.g. electromagnetic interferences causing transmission errors and bit-flips in memory), or when some characteristics of the system are not perfectly known or foreseeable beforehand, we model and analyze the uncertainties using stochastic models, for instance, models of the frame transmission patterns or models of the transmission errors. In the context of real time computing, we are in general much more interested by worst-case results over a given time window than by average and asymptotic results, and dedicated analyses in that area have been developed in our team over the last 10 years. An illustration, is our recent contribution to the extension of "consecutive-k-out-of-n:F" analyses, applied to the reliability evaluation of X-by-Wire systems [48], [51]. As far as the design of discrete event systems is concerned, we mainly use scheduling techniques for real time systems.
In the design of discrete event systems with hard real time constraints, the scheduling of the system's activities is of crucial importance. This means that we have to devise scheduling policies that ensure the respect of time constraints on line and / or optimize the behavior of the system according to some other application-dependent performance criteria. A new approach to solve these problems was partially developed in our team: the trajectory approach with priority functions. This approach has been used many times to make formal proofs of schedulability results in quite general cases. Another line of research investigated in our team is the use of techniques originating from network calculus, with the aim of minimizing the set of assumptions about the system's behaviour.

Many current systems can adapt dynamically to the environment [49], [50], [46], [45]. This is why we focus on "weakly hard" real time constraints such as (m, k)-firm constraints and study their applicability in two main application fields. The first one is concerned by application under weakly hard constraints, as real time multimedia application that are deployed for example on internet; in this case, the main problem is to adapt the (m, k)-pattern to the current requirements in terms of real time Quality of Service. The second domain where these techniques are investigated is the co-design of networked control systems. It has to be noted that in this domain several approaches are developed by the community; some of them focus on the automatic control problem and try to solve it by delayed systems while other ones are concerned only by the scheduling techniques to implement in order to guarantee the timing properties required by the closed loops. In this context, we propose to specify how to scale both control law parameters and scheduling strategies for tasks and messages and, for this purpose, we integrate control theory (linear systems, multi-variables), optimisation and schedulability analysis in order to develop off-line and on-line techniques [45], [47].

4. Application Domains

4.1. Application Domains

Four main application domains can be underlined.

- **In-vehicle embedded systems.** A lot of work developed in TRIO is oriented towards transportation systems (cars, autonomous vehicles, etc.). They mainly cover two points. The first one is the specification of what must be modeled in such a system and how to reach a good accuracy of a model; this leads to investigate topics like Architecture Description Languages and automatic generation of models. The second point concerns the verification of dependability properties and temporal properties required by these applications and, consequently, the development of new fault tolerant on-line mechanisms to include in an application or the automatic generation of a standard middleware.
- **Compilation, memory management and low-power issues for real time embedded systems.** It is mandatory, in a context of environment preservation, to design embedded systems that respect performances and reliability constraints while minimizing the energy consumption. Hence, TRIO is involved, on the one hand, in the definition of adhoc memory management at compilation time and on the other hand, in joint study of memory management strategies and tasks scheduling for real time critical systems.

- **Quality of services (QoS) of protocols and telecommunications.** In many application domains, the evaluation and, when required, the improvement of the quality of services provided by the used communication protocols is a way to ensure the respect of real time and dependability properties. In this context, we model and analyze some protocols for internet and cyber physical systems and aim to define the optimal configuration of their characteristics (protocols for the QoS guarantee for multimedia applications or ambient assisted leaving applications).
- **Code analyses and software visualization for embedded systems.** Despite important advances, it is still impossible to develop and optimize automatically all the programs with all their variety, especially when deployment constraints are considered. Software design and implementation thus remain highly ad-hoc, poorly automated activities, with a human being in the loop. TRIO is thus involved in the design of better tools for software engineering focusing on helping the human developer understand and develop the system, thanks to powerful automated program analyses and advanced visualizations techniques.

5. Software

5.1. Diatélic

Participant: Jean-Pierre Thomesse.

After having developed (in 2002) the well-suited structure for the deployment of the "Diatélic" service in Lorraine, more than 200 patients have been installed and get benefits from the remote monitoring service for peritoneal dialysis therapy. This deployment has been very rich in experience for extending an innovative system at a wide scale. In terms of medical results, the same tendencies are observed as during the experiment (1999-2002); i.e. best control of weight, of blood pressure, less consumption of drugs and important decreasing of the hospitalization duration (50 %), leading to an economy for health insurance of about 15 000 euros per year and per patient.

5.2. SPECO: Software Platform to Evaluate the impact of Compilation Optimizations

Participants: Maha Idrissi Aouad, Olivier Zendra.

This platform aims at automatically running a large number of benchmarks and thus get precise concrete results over the actual impact of any compilation optimization we design in our research. The benchmarks have been chosen among the most relevant according to the bibliography, and mostly comprise multimedia and embedded systems related programs. The platform works as follows. It extracts static metrics to provide information about the structure and static complexity of the benchmarks. It compiles all the benchmarks, and runs them to extract dynamic metrics helping characterize the behavior of programs at run-time. Those dynamic metrics comprise time, for raw performance, and space (memory) information to better understand the memory behavior of the programs. A second version was developed in 2007-2008. It now integrates the energy usage metric. This metric is indeed an important part for our current research work, for example in the ANR MORE project, where SPECO is used to characterize programs and obtain some of the metrics needed in MORE for the iterative compilation framework we are developping with our ANR MORE partners (see this software below). This new version also comprises the semi-automated generation of graphs to complete the text-based results we have already provided. Future developments should include automating the installation of our software platform and making sure it runs on a variety of hardware platforms.

5.3. ANR MORE platform

Participants: Maha Idrissi Aouad, Olivier Zendra.

With three partners (LIP6 in Paris, IRIT in Toulouse, and INRIA-LORIA), the ANR MORE (Multicriteria Optimization for Real time Embedded systems) project aims at developing trade-off strategies that transform the code of a critical embedded application so that it meets the system constraints in terms of worst-case execution time, code size and energy consumption. In this project, INRIA-LORIA focuses on memory optimizations for energy under real time constraints. With our partners, we are developing in this project an iterative optimization process that will help in driving the selection of the transformations to apply according to measures carried on the system (through a simulator provided by the IRIT partner). We have worked this year on building the software bases for the experimental platform. More precisely, we have been developing measure tools for the energy part and for memory characterization (partly based on SPECO) and have been working on their integration with and into the libraries ands simulator provided by our IRIT partner, and with the code compression extension provided by our LIP6 partner. The very next developments will be the coding of memory-related code transformations within our common platform for MORE.

5.4. NETCARBENCH: a benchmark for broadcast network

Participants: Mathieu Grenier, Lionel Havet, Nicolas Navet.

We propose a new benchmark for broadcast networks in automotive distributed control systems, called NETCARBENCH. The main contribution of NETCARBENCH is to allow a fine-grained user-defined parameterization of the generated message sets by means of XML configuration files that specify the characteristics of the message sets and the variability thereof. In addition to the program itself, configuration files of typical body and chassis networks are provided. NETCARBENCH, and all the accompanying material, are licensed under the GNU General Public License version 2 (http://www.loria.fr/~nnavet/netcarbench/).

6. New Results

6.1. Real time services and protocols

In this area, we developed, on the one hand, policies for managing the quality of service of operating support (mainly, networks and protocols) in order to meet the properties required by real time applications (hard real time, weakly hard real time) and, on the other hand, strategies for scheduling activities and memory management.

6.1.1. Fine tuning MAC level communication protocols

Keywords: *Controller Area Network*, *communication protocols*, *computer-controlled system*, *feasibility*, *fieldbuses*, *performance optimization*.

Participants: Mathieu Grenier, Nicolas Navet.

In distributed real time systems, meeting the real time constraints is mandatory but the satisfaction of other application-dependent criteria is most generally required as well. In particular, Networked Control Systems (NCS) are known to be sensitive to communication delays such as frame response time jitters. Well known Medium Access Control (MAC) algorithms such as Non-Preemptive Deadline Monotonic (NP-DM) or Non-Preemptive Earliest Deadline First (NP-EDF) are efficient in terms of bandwidth usage but they may perform poorly regarding other application dependent performance criteria. In [11], we highlight a class of on-line scheduling policies targeted at scheduling frames at the MAC level, and provide a schedulability analysis that is valid for all policies within the considered class. As it is shown in [11], these algorithms are implementable on COTS components (e.g., Controller Area Network controllers) and offer good trade-offs between feasibility and the satisfaction of other application-dependent criteria such as the response time jitter.

6.1.2. Low-power multi-processor scheduling

Keywords: *low-power*, *multiprocessor*, *real time*, *scheduling*.

Participants: Nicolas Navet, Vincent Nélis [Université Libre de Bruxelles], Joël Goossens [Université Libre de Bruxelles].

Many power-constrained embedded systems are built upon multiprocessor platforms because of high-computational requirements and because multiprocessing often significantly simplifies the design. Another advantage is that multiprocessor systems are theoretically more energy efficient than equally powerful uniprocessor platforms because raising the frequency of a single processor results in a multiplicative increase of the consumption while adding processors leads to an additive increase.

In [26], we address the power-aware scheduling of sporadic constrained-deadline hard real time tasks using dynamic voltage scaling upon multiprocessor platforms. We propose two distinct algorithms. Our first algorithm is an off-line speed determination mechanism which provides an identical speed for each processor. That speed guarantees that all deadlines are met if the jobs are scheduled using EDF. The second algorithm is an on-line and adaptive speed adjustment mechanism which reduces the energy consumption while the system is running.

6.1.3. Low-power and low-energy in embedded and/or real time systems

Keywords: *adaptation*, *cache*, *compilation*, *energy consumption model*, *low-power*, *memory management*, *scratch-pad memory*.

Participants: Maha Idrissi Aouad, Olivier Zendra.

Work in this domains is performed in the context of the ANR MORE (Multicriteria Optimization for Real time Embedded systems) project, which involves three partners (LIP6 in Paris, IRIT in Toulouse, and us). This year, we first worked with our partners on refining our set of suitable benchmarks. This task was not easy, since benchmarks that allow us to evaluate the tree criteria — code size, energy and Worst Case Execution Time — are not very common. Indeed, most benchmarks and benchmark suites target only one criterion. We also worked on the characterization of these benchmarks from a memory and energy point of view. We realized the tools available for energy characterization were obsolete and barely usable (with the exception of CACTI for caches) and are thus implementing directly in the common platform what we could not find "off-the-shelf". We designed an appropriate grammar for the description of the memory architecture of systems, with the relevant pieces of information (timings and energy usage) for our work.

6.1.4. Architecture-aware compiler solutions for energy issues in embedded systems

Keywords: *architecture*, *code analyses*, *compilation*, *embedded systems*, *hardware*, *low-energy*, *low-power*.

Participant: Olivier Zendra.

This work is done in an HiPEAC1 cluster that aims at bringing together researchers and practitioners both from academia and industry in order to address energy issues in embedded systems from a compilation point of view. We want not only to study one specific energy optimization, but also to take a holistic, broader view to explore interactions and synergies between several (compiler) optimizations at the same time. We are above all convinced that compiler optimizations should be "hardware-aware", and that more information exchanges between hardware and compiler are mandatory to be able to perform the best energy optimizations. With our partners (Thales, Intel and Univ. of Edinburgh), we have so far defined our experimental application domain (software radio for embedded systems) and target processors. We are developing our main benchmark and experimental platform.

6.1.5. Networked control systems: resource overload management using selective data dropouts according to (m, k)-firm model

Keywords: *Admission control*, *Network*, *Networked control systems*, *Real time QoS*, *co-design*.

Participants: Flavia Felicioni [Rosario University, Argentina], Ning Jia, François Simonot, Françoise Simonot-Lion, YeQiong Song.

We complete the results obtained previously in two directions. The first one aims to identify a condition under which the stability of a monodimensional and linear system is ensured. Then we developped an algorithm for the optimal specification of the (m, k)-constraint to be applied to such system distributed over a network (this work is part of the PhD of Ning Jia; the defense is forcasted in January 2009). The criteria to minimize were the upper bound of the variance of the system state. The second point concerns the optimal codesign (resource minimisation and control performance optimisation) the handling of a set of control loops, each of them being implemented as an OS task and all the tasks sharing the same processor. We distinguished three different situations of controlled plant states: not activated, steady state situation and transient situation. The infinite-horizon and finite-horizon cost functions are respectively used to represent the performance of each control task in the last two situations. We propose a scheduling architecture in which, according to the plant state situation, the task handler switches between these two types of performance criterion to determine an on-line (m, k)-constraint based control task scheduling strategy, so that the overall control performance is maintained at a high level in each situation subject to the task schedulability. The approach is exemplified on a set of controllers for different plants [21], [22].

6.1.6. QoS mechanisms in multi-hop wireless sensor networks

Keywords: *Real time QoS*, *Routing protocols*, *Wireless sensor network*, *performance evaluation*.

Participants: Najet Boughanmi, Bilel Nefzi, Yanjun Li, René Schott, Jamila Ben Slimane, YeQiong Song.

Our previous investigations on WSN have shown a great need on introducing new mechanisms to enhance the QoS for supporting time-constrained or more generally performance-requiring applications. We have focused on four important points: network connectivity [13], QoS routing [28], [29], [30], Channel allocation [40] and packet scheduling [25].

For improving routing performance, we have focused on geographic routing protocols and proposed the idea of using multi-hop neighbourhood information instead of one-hop based. At first, in [28], we explored the asymptotic performance of existing geographic routing with a utilization of k-hop neighborhood information. The reachability from source to sink improves as we use more information for routing decision and the average number of hops required decreases significantly from 1-hop to 2-hop searching, which indicates a potential trade-off between performance enhancement and system complexity. As simple greedy geographic routing is insufficient in lossy wireless environment, we propose a new metric incorporating both advance in distance and link quality. Through simulations, we show its effectiveness over the conventional simple greedy method. The generalization to k-hop based routing and resulting performance are also presented. Simulation results show that with the multi-hop based searching, there is a good improvement in the number of transmissions required from source to sink, which also indicates potential improvement in routing delay and energy consumption in transmissions. Then, based on the above study, in [29] and [30], a 2-hop neighbourhood information based routing protocol is proposed for real time wireless sensor networks. The approach of mapping packet deadline to a velocity is adopted as SPEED; however, our routing decision is made based on the novel 2-hop velocity. Energy efficient probabilistic drop is embedded to enhance energy utilization efficiency while reducing packet deadline miss ratio. In case packet deadline requirement is not stringent, a new mechanism is included to release nodes that are frequently chosen as forwarders. Improvement on energy consumption balance throughout the network is observed. The true characteristics of physical and MAC layers are captured in the simulation. A real lossy link model is drawn from extensive experiments through Mica2 Motes. Simulation results show that the new protocol has achieved lower packet deadline miss ratio and higher energy efficiency.

Connectivity is a fundamental issue in research on wireless sensor networks. However, unreliable and asymmetric links have a great impact on the global quality of connectivity (QoC). In [13], we studied the impact of link unreliability and asymmetry on the quality of connectivity in large-scale sensor networks. By assuming the deployment of nodes to be a homogeneous Poisson point process and eliminating the border effect, we derived an explicit expression of node non-isolation probability as the upper bound of one-connectivity, based on an analytical link model which incorporates important parameters such as path loss exponent, shadowing variance of channel, modulation, encoding method etc. The derivation has built a bridge over the local link property and the global network connectivity, which makes it clear how various parameters

impact the QoC. Numerical results obtained further confirm the analysis and can be used as reference for practical design and simulation of wireless ad hoc and sensor networks. Besides, we find that giant component size is a good relaxed measure of connectivity in some applications that do not require full connectivity.

The use of multiple frequency channels can greatly improve the network performance. Both IEEE 802.15.4 and 802.15.4a (UWB) standards allow for dynamic channel allocation and use of multiple channels available at their physical layers but its MAC protocols are designed only for single channel. Also, sensor's transceivers such as CC2420 provide multiple channels and channel switch latency of CC2420 transceiver is very short just about 200 micro seconds. In [40] we have proposed a new MAC protocol allowing multi-channel allocation for 802.15.4a compliant devices. This MAC protocol is shown energy efficient and provides shorter end-to-end delay.

Packet scheduling plays an important role for providing differentiated services in WSN. However unlike wired link, wireless link does not allow to queue different traffic flows in different queues and thus well-known scheduling policies such as WFQ cannot be directly applied. In [25], we have proposed a network-MAC cross layer design for enabling the implementation of scheduling policies by resolving some problems related to the wireless environment. This design is based on CSMA/CA and offers a low complexity, which makes it suitable for Wireless Sensor Networks. The idea of N-MAC is that a router collects data from its children and other routers before starting their transmission. This way offers the possibility to schedule arrived packets, perform data aggregation and congestion control more easily.

6.1.7. Supporting distributed real time applications using wireless networks

Keywords: *Real time QoS*, *Remote monitoring*, *Wireless sensor network*, *performance evaluation*.

Participants: Najet Boughanmi, Bilel Nefzi, Shahram Nourizadeh, YeQiong Song, Jean-Pierre Thomesse.

The use of wireless networks for supporting real time applications is becoming more and more attractive. However there exist few available solutions. Besides the enhancement of the QoS of the network itself, one must also care about the adaptation of the provided QoS to the real time application requirements. On this point we have taken the example of Zigbee/IEEE802.15.4 network for investigating its suitability to supporting control applications where a control loop is closed through a wireless network [16]. The network is considered as a common resource shared by other applications. As the non beacon-enabled mode of IEEE 802.15.4/ZigBee does not ensure the stability for the control loop since there is no mechanism that can prevent the perturbation coming from the other applications sharing the same network, we investigated the beacon-enabled mode using the Guaranteed Time Slot (GTS) mechanism and showed its suitability and limits. For this purpose an extension of the Zigbee package of TrueTime software including now the beacon-enable mode has been implemented. Further investigations aim to develop an adaptive mechanism to allow on-line network parameters adjustment according to the application requirements.

Considering a remote monitoring system for providing an ambient assisted living environment to elderly people at home (1st year of the PhD work of S. Nourizadeh under LORIA-MEDETIC contract), we also addressed the problem of the integration of WSN into the existing home automation networks. A first demonstration platform has been settled down and the integration of WSN is ongoing.

6.2. Evaluation and optimal scaling of real time systems

6.2.1. Real time multiprocessor scheduling

Keywords: *multiprocessor scheduling*, *parallel tasks*, *periodic schedules*, *schedulability analysis*.

Participants: Liliana Cucu, Sébastien Collette [Université Libre de Bruxelles], Joël Goossens [Université Libre de Bruxelles].

We deal in this topic with scheduling of tasks on different processors; the schedule must be done such that the deadlines are satisfied. These results belong to two different models of tasks: tasks that can be executed on at most one processor at one time instant and tasks that can be executed in parallel on several processors in the same time.

- For the classical model of tasks, we give in [17] a new proof of complexity for multiprocessor scheduling of periodic tasks. Contrary to the general (not proved) opinion, the problem of having an optimal fixed-priority scheduler for periodic tasks is not NP-hard. A new algorithm is proposed to decrease the complexity and to show that the scheduling problem with fixed-priority is polynomial.
- Concerning the tasks that can be executed in parallel on several processor in the same time, we introduce in [9] a multiprocessor model of parallel tasks. We provide an optimal polynomial algorithm for the case of identical processors. Therefore we prove that the given problem is polynomial. For the problem of unrelated processors, we propose in [18] a linear programming formulation of the problem.

6.2.2. Traffic shaping on real time LANs using offsets

Participants: Mathieu Grenier, Lionel Havet, Nicolas Navet.

In embedded electronic architectures, optimizing the use of the network bandwidth becomes crucial because of the increasing use of electronics leading to increasing transmissions on the networks. One solution that is being investigated by OEM such as car manufacturers is to schedule the messages with offsets, which leads to a desynchronization of the message streams. As shown in [24] and [32], this traffic shaping strategy is very beneficial in terms of worst-case response times. We also address in these publications the problem of choosing the best offsets in the case of Controller Area Network, which is a de-facto standard in the automotive world. Comprehensive experiments give insight into the fundamental reasons why offsets are efficient, and demonstrate that offsets actually provide a major performance boost in terms of response times. These experimental results suggest that, in the automotive field, sound offset strategies may extend the lifespan of CAN further, and may delay the introduction of FlexRay and additional CAN networks.

6.2.3. Stochastic scheduling of real time systems

Keywords: *CAN*, *schedulability analysis*, *stochastic scheduling*.

Participants: Liliana Cucu, Mathieu Grenier, Nicolas Navet, René Schott.

We deal here with stochastic scheduling of real time systems. Since some parameters of a system can be unknown until the time instant when the activity is released or the environment can change forcing the application to adapt, we need to consider an approach able to address this type of scheduling and we investigate the use of probabilistic approaches to solve this problem. In such approaches we handle two aspects, the schedulability analysis and the validation of the proposed analyses:

- Stochastic schedulability analyis for CAN. We propose in [19] a stochastic formulation on CAN that extends previous results obtained for uniprocessor fixed-priority scheduling of tasks with the interarrival times given by random variables. More precisely, we add the non-preemptive aspects using the latest deterministic formulation for CAN.
- Validation method for stochastic schedulability analysis of real time systems. The principles of this method were given in [20]. We obtain a complete presentation of this method through an application on a simple case of uniprocessor stochastic analysis. The validation indicates that the formulation given for the uniprocessor case was not correct since it does not provide the worst case response time.

6.2.4. Distributed algorithms and time-changing environment

Keywords: *Markov chain*, *probabilistic analysis*, *random graph*.

Participant: René Schott.

Our work on real time systems and wireless networks had highlighted more theoretical problems belonging to the area of non-homogeneous Markov chains and to the random geometrical graphs. Two collaborations, one with Francis Comets and François Delarue (LPMA, Paris 7) and another with G. Stacey Staples (Southern Illinois University at Edwardsville) provided several publications [14], [15], [44], [43]. More precisely, the first collaboration concerns the analysis of distributed systems in a Markov ergodic environment. The second collaboration deals with transition matrices, the convexity and the evolution of random graphs.

6.2.5. Robustness evaluation for a critical distributed system

Keywords: *control*, *deployment modeling*, *error models*, *stability*.

Participants: Lionel Havet, Françoise Simonot-Lion, Shanawaz Syed.

In the context of the CRISTAL project (adaptive system of platooning), we defined a modeling technique and a method to apply it for the robustness evaluation of a given deployment of platooning strategies. The main issue is to combine, thanks to the same modeling language, an effective model of the platform (performances, communication protocols, scheduling strategies) and the pertinent abstraction of the platooning algorithms themselves. We solve this problem by identifying an adhoc structure of the system and of its deployment that allows to model them with Matlab/Simulink language and the use of the specific TrueTime toolbox (from Lünd University). We developped two models: one of them based on the approach provided by the LASMEA (explicit communications between the different vehicles) and the other one based on the method given by the INRIA IMARA action (sensor based strategies). Thanks to these models, we are able to calculate, on the one hand, the worst acceptable delay for each action (transmission of information through wireless communication, internal transmission in each vehicle, execution time of each algorithm) and, on the other hand, the robustness of a strategy under transient failures. For this last point, we provided certain error models.

6.2.6. Robust deployment of a real time in-vehicle embedded middleware

Keywords: *discrete optimisation*, *frame packing*, *in-vehicle embedded system*, *real time*, *schedulability*.

Participants: Liliana Cucu, Xavier Grandmougin, Nicolas Navet, Françoise Simonot-Lion.

This study is part of the PREDIT-SCARLET project. This year we obtained two results. The first one is a software tool; it concerns the automatic generation of the so-called "frame-packing" and provides four different algorithms. Presently, on the one hand we are extending this tool in order to integrate certain features: the triggered characteristic of signal and a predefined set of frames. On the other hand, we start to study how to evaluate the robustness of a solution given by each algorithm in presence of several transient faults (delayed signals, delayed frames, etc.) The second result is an analysis of the AUTOSAR specification (the consortium AUTOSAR specified a reference architecture of in-vehicle embedded systems and each component of the middleware in order to provide a common set of services to application components); we identified 11 problems and their impact on the design of fault tolerant mechanisms: non-consistent specifications, non deterministic specifications, lack of behavioural and timing charcterization of the components and of their composition, etc. [42].

7. Contracts and Grants with Industry

7.1. PSA-Peugeot Citroën contracts - Configuration of TDMA-based networks

Participants: Mathieu Grenier, Nicolas Navet, Françoise Simonot-Lion.

The aim of this collaboration (December 2007-Juillet 2008) between TRIO and PSA Peugeot-Citroën was to come up with techniques and algorithms for the configuration of a FlexRay network given the communication requirements of a in-vehicle distributed application. This problem is NP-hard and the techniques developed were heuristics, with performance guarantees in certain contexts. Some results on which this study is based have been published in [23].

7.2. PSA-Peugeot Citroën contracts - End-to-end time contraints in an AUTOSAR context

Participants: Aurélien Monot, Nicolas Navet, Françoise Simonot-Lion.

The objective of this project (October 2008-September 2011) between TRIO and PSA Peugeot-Citroën is to provide a framework for the validation and the building of deployment of in-vehicle applications compliant with AUTOSAR standard. This study targets both accuracy of models, specification of analysis and optimal deployment methods and recovery mechanisms. This contract is related to the PhD Aurélien Monot (CIFRE grant).

7.3. Medetic - Remote monitoring for elderly people

Participants: Sharham Nourizadeh, YeQiong Song, Jean-Pierre Thomesse.

The topic of this contract is the development of a system for remote monitoring of the health and activities of old people at home. A new CIFRE grant has been obtained in October 2007 for a collaborative research project with MEDETIC in the form of the PhD thesis of Sharam Nourizadeh. The research goal is twofolds. The first one aims to develop QoS mechanisms in wireless sensor networks for supporting the application constraints in terms of communication reliability and response time. The second one consists in developing a modelling technique allowing the proper description and configuration of the whole system (based probably on the component approach and web service technology). Real world test bed installed by Medetic will allow the validation of our solution.

8. Other Grants and Activities

8.1. National Grants

8.1.1. ANR Project "Architectures du Futur" - Multicriteria Optimizations for Real time Embedded systems (MORE)

Participants: Maha Idrissi Aouad, Olivier Zendra.

The MORE project begun in 2007. Gathering three Partners (LIP6 in Paris, IRIT in Toulouse, and INRIA-LORIA), it aims at developing trade-off strategies that transform the code of a critical embedded application so that it meets the system constraints in terms of worst-case execution time, code size and energy consumption. In a first stage, it will consist in analyzing the effects of a set of transformations (modifications of the control flow, code and data placement and compression, etc.) on the three criteria to identify their interactions. Then, an iterative optimization process will be set up, that will help in driving the selection of the transformations to apply according to measures carried on the system (through a simulator). An algorithm for searching trade-offs between the three criteria will decide among the collection of possible solutions produced by the iterative process. The third stage will consist in learning from the obtained results to propose new code transformations, with their hardware support, that would make it possible to reach more efficiently better trade-offs. The MORE project includes an experimental part that will necessitate to develop a software framework integrating measure tools, code transformation routines and a driver to implement the iterative optimization process and the trade-off search. in this project, INRIA-LORIA focuses on memory optimizations for energy under real time constraints.

8.1.2. PREDIT Project - Systèmes Critiques pour l'Automobile : Robustesse des Logiciels Embarqués Temps-réel (SCARLET)

Participants: Liliana Cucu, Xavier Grandmougin, Nicolas Navet, Françoise Simonot-Lion.

This project proposed by the competitivity pole System@tic / Num@tec Automotive will be financed by ANR / PREDIT Program. It started in January 2007. The purpose of this project is to define methods and services that ensure the reliability of software COTS when integrating them in a critical embedded system. In SCARLET, TRIO is involved in tasks that aim to specify a methodology for the correct and optimal deployement of a real time system. A good input of this research were the works done by Ricardo Santos Marques during his PhD. In 2008, we mainly focused on mecanisms that are compliant to AUTOSAR.

8.1.3. "Pôle de Compétitivité Alsace Franche-Comté" and FCE - CRISTAL Project

Participants: Xavier Grandmougin, Lionel Havet, Françoise Simonot-Lion.

The context of the CRISTAL project is a new transportation system for cities. The project gathers town planning consultants and scientifics. The role of the latter ones is to study an adaptive system of platooning, i.e. a system operating electrical vehicles under precise automatic control at close spacings to form a platoon. In particular, for TRIO, the challenge is to specify an optimal deployment of embedded functions that ensures by construction the safety properties required by the European regulation. The LORIA research teams involved in this project are DEDALE, MAIA and TRIO. The partners are Lohr Industry, VU-log, Transitec.

8.1.4. ARA SSIA SAFE_NECS

Participants: Flavia Felicioni, Ning Jia, François Simonot, Françoise Simonot-Lion, YeQiong Song.

Since December 2005, TRIO participates to the ARA SSIA Safe_NECS national project under ANR grant n° ANR-05-SSIA-015. The context of this project is the design of embedded systems whose function is the fault tolerant control of continuous process and whose implementation is done onto a distributed platform (Networked Control Systems). In particular, the project aims to develop a "co-design" approach that integrates in a coordinated way several kinds of parameters: the characteristics modelling the Quality of Control (QoC) as given by automatic control specialists, the dependability properties required on a system and the parameters of real time scheduling (tasks and messages). This year, we proposed several techniques for the co-design of control laws and scheduling strategies of tasks that implement them for a centralized architecture.

8.1.5. ANR Open-PEOPLE

Participants: Nicolas Navet, Ye-Qiong Song, Olivier Zendra.

The aim of Open-PEOPLE is to provide a platform for estimating and optimising the power and energy consumption of systems. Users will be able to estimate the consumption of an application running on a hardware architecture chosen in a set of parametric architectures. In the system, components will be chosen in a library of hardware and software components, parametric or not. Estimation will be possible from different levels in the specification refinement: the underlying methodology will use multi-level interchangeable and interoperable consumption models, to allow for an easy exploration of the design space. It will be possible to use estimation results to check the energetic features of a system developed with a distinct simulation platform. Information in return, regarding functional properties of the application, will permit to further refine estimation results in Open-PEOPLE. Standardization of consumption models will be proposed, to allow for interchangeability and interoperability, and to ease the exchange of data between different platforms. The Open-PEOPLE library of consumption models will be extensible: new component models will be added, following the needs of its users, and the technology evolution. To this effect, the software estimation platform will be accessible through an internet portal, and will be coupled to a hardware platform supporting the automation of physical measures. A library of benchmarks will be proposed to permit the characterization of new components and architectures. In addition to the necessary works on the methodology for multi-level consumption estimation of heterogeneous and complex systems, additional research works will make it possible to propose methods and techniques for the optimization of consumption based on Open-PEOPLE estimation results. Thus, Open-PEOPLE is turned both towards academic users in support of research works on consumption estimation and optimisation methods, and towards industrial users for system design. Open-PEOPLE consortium will stay open. New members will have the possibility to join at any time, to benefit from the project results or to collaborate to different works. Open-PEOPLE will start at the end of 2008.

8.1.6. CONECS

Participants: Laurent Ciarletta, Françoise Simonot-Lion, Ye-Qiong Song.

CONECS (Co-design Of NEtworked Control Systems) aims at developing a methodology of integrated co-design of dependable networked control systems. This approach should consider in a coordinated way the quality of control (QoC), the properties of dependability, and the task and message scheduling policies on the support system (processors and networks). This project has been accepted by GIS 3SGS. It is a common project between LORIA and CRAN (with Dominique Sauter of CRAN as the project coordinator). TRIO team will mainly contribute to developing adaptive QoS control algorithms and on-line mechanisms in networks that should take advantage of the fine knowledge on the application requirements of the control and monitoring loops. This project will start at the end of 2008 with the recruitment of a post doctoral fellow of 6 months.

8.1.7. COWNECS

Participants: Najet Boughanmi, Liliana Cucu, Flavia Felicioni, Bilel Nefzi, Jamila Ben Slimane, Françoise Simonot-Lion, Ye-Qiong Song.

COWNECS (Co-design Of Wireless NEtworked Control Systems) is a common project between LORIA (with Y.Q. Song as project coordinator), CRAN and LICM funded by Lorraine region as part of CPER SSS and SafeTech frameworks. Its aim is similar to that of CONECS but with a strong emphasize on the wireless network QoS adaptation for supporting dependable control applications. It is also complementary with CONECS by providing necessary equipments for building a platform to show the interest of our co-design approach. This platform is a high speed travelling crane with supervision, control and diagnostic through standard wireless networks (WiFi and Zigbee). The dependability guarantee of such applications implemented over unreliable wireless networks consists in a challenge and calls for developing efficient on-line mechanisms at both MAC and routing level. The project has started in October 2008.

8.2. European Projects

8.2.1. NOE High Performance Embedded Architecture an Compilation (HiPEAC)

Participant: Olivier Zendra.

The TRIO team is involved in the HiPEAC (High Performance Embedded Archiotecture and Compilation) European Network of Excellence (NoE). Olivier Zendra is initiator and leader in this context of a cluster of European Researchers “Architecture-aware compiler solutions for energy issues in embedded systems” since mid-2007.

8.3. International Cooperations

8.3.1. Research program INRIA-Tunisia STIC07/I08 on QoS study of wireless sensors and actuators networks

Within this program between TRIO ARMOR-IRISA and SUPCOM Tunis we mainly aim to provide real time QoS in order to be able to support real time applications either using the current wireless sensor network technologies or their improvement. IEEE802.15.4 and Zigbee have been the two main investigated protocols for this first project year. Ye-Qiong Song has visited SUPCOM Tunis as part of the INRIA-Tunisia program STIC07/I08 in August and December 2007.

8.4. Visits

In 2008 TRIO has invited, for short term visit, Stefan Petters, NICTA, Australia, Professor Wang Zhi, Zhejiang University, China, Frikha Mounir and Tabbane Nabil, INIT, SupCom, Tunisia.

8.5. Action for the research community

- Members of TRIO are elected to CSE of sections 27, 61 and 63.
- Nicolas Navet is member of the “Espace transfert” committee (industrial transfer) of the LORIA.
- Françoise Simonot-Lion is member of the expert committee of the GDR ASR/ASERT,
- Françoise Simonot-Lion was, until July 2008, elected member of the administration board of Institut National Polytechnique de Lorraine and is presently elected member of the administration board of École Nationale Supérieure des Mines de Nancy.
- Jean-Pierre Thomesse is DRRT at Region Lorraine.
- Françoise Simonot-Lion is member of the Program committee of INRIA-Lorraine
- Françoise Simonot-Lion co-chairs with Steve Hung (Clemson University, USA) the subcommittee “Automotive Electronic and Embedded Systems” of the IEEE Industrial Electronic Society (IES) - Technical Committee on Factory Automation (TCFA).
- Nicolas Navet co-chairs with Thomas Nolte (MRTC Mälardalen) the Sub-Committee on ”Real Time Fault Tolerant Systems” of the IEEE Industrial Electronic Society (IES) - Technical Committee on Factory Automation (TCFA).
- Françoise Simonot-Lion is Member of the Advisory Board of the “Embedded Systems Handbook” at CRC Press.
- Françoise Simonot-Lion and Olivier Zendra are elected members of LORIA Laboratory Council.
- YeQiong Song is the responsible of the "research by training" of CRI Nancy - Grand Est, the head of the committee for INRIA postdoctoral and CORDI PhD candidates examination and recruitment of CRI Nancy - Grand Est ; he is member of the Computer Science DFD committee.
- Olivier Zendra is Head of Documentation Committee of INRIA-Lorraine.
- Nicolas Navet was external assessor for a funding application on real time communication for the ”Fonds québécois de recherche sur la nature et les technologies” and for a funding application on Time-Triggered Technologies for the Austrian Science Fund.
- YeQiong Song was reviewer for the PhD of Ahmed Rahni (Université de Poitiers); Françoise Simonot-Lion was reviewer for the PhD of Benjamin Fontan (INPT, Toulouse), Eric Armengaud (Technical University of Vienna, Austria), Kaj Hänninen (Mälardalen University, Vasteras, Sweden), Huafeng Yu (Université de Lille), Rachid Bouaziz (Université de Toulouse) and for the HdR of Samia Bouzefrane (Université de Lille); Jean-Pierre Thomesse was reviewer for the PhD of Sylvain Bonhomme (INPT, Toulouse) et Jackson Francomme (Université de Toulouse le Mirail); René Scott was reviewer for the HdR of Bartek Blaszczyszyn (Université de Wroclaw, Pologne) and have done the tenure report for Jurek Kocik (Southern Illinois University at Carbondale).
- Permanent members of TRIO were jury members for the PhD defense of Olivier Christmann (UHP Nancy 1 - YeQiong Song), Walid Htira (LAAS, Toulouse - Nicolas Navet), Damien Masson (Université Paris Est, Marne la Vallée - Nicolas Navet), Raghav Aras, Stefan Canzar and Szilard Vajda (LORIA - René Schott).

8.6. Colloquium, seminars, invitations

- Françoise Simonot-Lion was invited to give two seminars on ”Optimal configuration of an in-Vehicle Embedded Middleware” and on ”Dependability Evaluation of Real Time Applications Distributed on TDMA-Based Networks” at Techical University of Vienna.
- Ye-Qiong Song was invited by GIPSA Lab in Grenoble, to give a seminar on ”a state of the art on (m,k)-firm model and its use in QoS control”.

- Nicolas Navet was invited to give a talk entitled "Trends in Embedded Communication Systems: Traffic Shaping on CAN and Introduction of FlexRay", at the workshop "Les Systèmes Embarqués: Sécurité, Confort, Aide à la Conduite", ESIEE (Amiens, France, May 13, 2008) and a talk entitled "On Predictability and Profitability: Would AI Induced Trading Rules be Sensitive to the Entropy of Time Series?" at the 2nd Workshop: Bridging Mathematics, Natural Sciences, Social Sciences, and Finance, International University of Monaco, (April 9-11, 2008).
- Liliana Cucu was invited to give a talk at University of York (June 2008), at University of Luxembourg (April 2008) and at Dagsthul Seminar on Scheduling, Germany, February 2008 [20], [18].
- René Schott was invited to give a talk at "séminaire de probabilités" (Paris 6 et Paris 7), "séminaire TREC" (ENS-Ulm), Université de Dortmund (Allemagne).
- Françoise Simonot-Lion was program chair with Gianluca Cena (Politecnico di Torino) of IEEE WFCS'2008, (Dresden, Germany, May 20-23, 2008) [37]; she will be general co-chair of IEEE WFCS'2010 in Nancy (May 2010).
- Nicolas Navet was Program Co-Chair of the 3rd IEEE Symposium on Industrial Embedded Systems (SIES'2008)(Montpellier, France, June 11-13, 2008), Work-in-Progress Chair with Thomas Nolte (MRTC Mälardalen) of the 7th IEEE International Workshop on Factory Communication Systems (WFCS'2008) (Dresden, Germany, May 20-23, 2008) and Publicity Co-Chair of the 14th IEEE International Conference on Embedded and Real Time Computing Systems and Applications (RTCSA 2008) (Kaohsiung, Taiwan, August 25-27, 2008).
- Liliana Cucu is co-chair of ROADEF session on real time scheduling (ROADEF'09). She will be also co-chair of invited session of real time scheduling at COGnitive systems with Interactive Sensors (SEE COGIS'09).
- YeQiong Song was program co-chair of TFIT08, session "Real time and embedded systems"
- Olivier Zendra was program chair of the Third International Workshop on Implementation, Compilation, Optimization of Object-Oriented Languages, Programs and Systems (ICOOOLPS 2008), July 7, Paphos (Cyprus); he is presently president of the organizing committee of LMO 2009 (15ème Conférence francophone sur les Langages et Modèles à Objets), CAL 2009 (3ème Conférence Francophone sur les Architectures Logicielles) and IDM 2009 (5èmes journées sur l'Ingénierie Dirigée par les Modèles) that will take place in Nancy in 2009.
- René Schott was program chair of the International Workshop on Mathematics in Computer Science (Paris, February 2008).
- Nicolas Navet and Françoise Simonot-Lion are steering committee members of the RTNS conference.
- Nicolas Navet is member of the editorial board of the Journal of Embedded Computing.
- Nicolas Navet and Françoise Simonot-Lion are editors of the CRC Handbook on "Automotive Embedded Systems", Taylor&Francis [39].
- Nicolas Navet and Françoise Simonot-Lion will be editors of the new series "real time and dependable systems", Taylor&Francis.
- Françoise Simonot-Lion is guest editor of IEEE Transactions on Industrial Informatics, special section "Automotive Embedded Systems" (to appear in 2009) and, with Gianluca Cena, from Politecnico Torino, of the IEEE Transactions on Industrial Informatics, special section "Communication in Automation".
- Liliana Cucu was program committee member for the IEEE Third Symposium on Industrial Embedded Systems (June 11- 13, 2008, Montpellier - La Grande Motte, France), International Conference of Principles of Distributed Systems (OPODIS'08), WIP session of IEEE Real-Time Systems Symposium (RTSS'08), Junior Researcher Workshop in Real-Time Computing (JRWRTC'08), International Conference on Advances in Electronics and Micro-electronics (ENICS'2008), Multidisciplinary International Scheduling Conference (MISTA'09).

- Nicolas Navet was program committee member for the 3rd International Workshop on Embedded Software Optimization (ESO 2008) (Shanghai, China, December 17 - 20, 2008), 2008 International Conference on Computational Intelligence and security (CIS'2008), (Suzhou,China, December 13-17, 2008), the 7th International Conference on Computational Intelligence in Economics and Finance (CIEF2008), (Taoyuan, Taiwan, December 5-7, 2008), the Track on High Performance Reconfigurable Computing in the 2008 International Conference on ReConFigurable Computing and FPGAs (ReConFig'08), (Cancun, Mexico, December 3-5, 2008), the Workshop on Simulation, Modelling and Data Management in Real-Time Systems (SMDM-RTS'2008, in conjunction with ESM'2008), (Le Havre, France, October 27-29, 2008), the 16th International Conference on Real-Time and Network Systems (RTNS'2008), (Rennes, France, October 16-17, 2008), the 5th IEEE Internationational Conference on Embedded Computing (SEC 2008), (Beijing, China, October 6-8, 2008), the International Conference on Advances in Electronics and Micro-electronics, (ENICS 2008), (Valencia, Spain, September 29 - October 4, 2008), the 13th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2008 - Tracks on: Real-Time and (Networked) Embedded Systems, Industrial Communication Systems, Information Technology in Automation), (Hamburg, Germany, September 15-18, 2008), the 14th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications (RTCSA 2008), (Kaohsiung, Taiwan, August 25-27, 2008), 2008 International Conference on Embedded Software and Systems (ICESS 2008), Chengdu, China, July 29-31, 2008), the IEEE International Conference on Sensor Networks, Ubiquitous and Trustworthy Computing (SUTC 2008), (Taichung, Taiwan, June 11-13, 2008), the 7th IEEE International Workshop on Factory Communication Systems (WFCS'2008), Dresden, Germany, May 20-23, 2008.
- René Schott was program committee member for International Workshop on Mathematics in Computer Science (Paris, February 2008).
- Françoise Simonot-Lion was program committee member for the 13th IEEE International Conference on Emerging Technologies and Factory Automation ETFA 2008 (Hamburg, 15-18 September 2008), ICESCA'2008, the track "Embedded Systems" of the IEEE Intl. Conference on Sensor Networks, Ubiquitous and Trustworthy Computing SUTC08 (June 5-7, 2008 Taichung, Taiwan), the Sixth IEEE Conference on Industrial Informatics (INDIN'08) (Daejeon Korea, July 13-16, 2008), the 16th International Conference on Real-Time and Network Systems, RTNS'2008, (October 16-17, 2008, Rennes, France), the IEEE Third Symposium on Industrial Embedded Systems (June 11-13, 2008, Montpellier - La Grande Motte, France), the Fourth Taiwanese-French Conference on Information Technology (TFIT 2008), (Taipei, Taiwan, March 3-5, 2008), the Workshop UML & AADL'08 held in conjunction with the thirteenth IEEE International Conference on Engineering of Complex Computer Systems (April 02 , 2008, Belfast, Norther Ireland).
- Ye-Qiong Song was program committee member for the 7th IEEE International Workshop on Factory Communication Systems(WFCS 2008) (May 20-23, 2008, Dresden, Germany), the 13th IEEE International Conference on Emerging Technologies and Factory Automation ETFA08 (Hamburg, Germany, September 15-18, 2008), the 7th International Workshop on Real-Time Networks RTN'08 held in conjunction with the 20th Euromicro International Conference on Real-Time Systems (Prague, Czech Republic, July 1, 2008), the track "Embedded Systems" of the IEEE Intl. Conference on Sensor Networks, Ubiquitous and Trustworthy Computing SUTC08 (June 5-7, 2006 Taichung, Taiwan), the Fourth Taiwanese-French Conference on Information Technology (TFIT 2008), (Taipei, Taiwan, March 3-5, 2008), the European Simulation and Modelling Conference 2008, ESM'2008 (October 27-29, 2008, Le Havre, France).
- Olivier Zendra was program committee member for the Third International Workshop on Implementation, Compilation, Optimization of Object-Oriented Languages, Programs and Systems ICOOOLPS 2008 (July 7, Paphos, Cyprus), the International Workshop on Advanced Software Development Tools and Techniques, WASDeTT 2008, 15ème Conférence francophone sur les Langages et Modèles à Objets LMO 2009 (Nancy), the 3ème Conférence Francophone sur les Architectures Logicielles CAL 2009 (Nancy), the 5èmes journées sur l'Ingénierie Dirigée par les Modèles

IDM 2009 (Nancy)

- The permanent members of TRIO team are reviewers for several international Conferences and Workshops and, in particular for the following journals: IEEE Transactions on Industrial Informatics (Nicolas Navet, Françoise Simonot-Lion, Liliana Cucu, YeQiong Song), Transaction on Computers (Françoise Simonot-Lion), IEE Proc. Communications (Françoise Simonot-Lion), Eurasip Journal (Françoise Simonot-Lion), IEEE Computer Communications (YeQiong Song), Journal of Discrete Event Systems (Nicolas Navet), International Journal of Mathematics and Computer Science, Journal of Theoretical Ptobability, Advances in Applied Probability, Notes aux Comptes Rendus de L'Académie des Sciences (René Schott).

8.7. Teaching activities

The permanent members of TRIO are teaching in INPL and Université Henri Poincaré-Nancy 1 (engineer schools and masters).

9. Bibliography

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