Center of Excellence for Research DEWS

Research Activity Report

DEWS

“Design methodologies of Embedded controllers, Wireless interconnect and Systems-on-chip”

www.dews.ing.univaq.it

Address:

Università degli Studi Dell’Aquila
Via G. Gronchi, 18
Nucleo Industriale di Pile
67100 L´Aquila (AQ) – Italy

University of L'Aquila

L'Aquila

June 2011

DEWS Staff

Director

- Maria Domenica Di Benedetto

Personnel

- Paolo Caravani
- Elena De Santis
- Maria Domenica Di Benedetto
- Stefano Di Gennaro
- Alessandro D'Innocenzo
- Fabio Graziosi
- Pierdomenico Pepe
- Giordano Pola
- Luigi Pomante
- Marco Pratesi
- Fortunato Santucci

Technical Staff

- Roberto Alesii

Post Doc

- Alessandro Borri
- Claudia Rinaldi
- Emmanuele Serra
- Francesco Tarquini
- Ubaldo Tiberi
- Stefano Tennina

PhD Students

- Domenico Bianchi
- Andrea Colarieti
- Maurizio Colizza
- Dario De Leonardis
- Piergiuseppe Di Marco
- Fabio Federici
- Mauro Ianni
- Michela Iezzi
- Laura Imbriglio
- Stefano Marchesani
- Alessandro Petriccone
- Marco Pugliese
- Francesco Smarra

DEWS Collaborations

Contents

Research Activity: overview

DEWS started its operations in 2001 after the Ministry of Scientific Research and University awarded grants for the formation of centers of excellence on a competitive basis. DEWS was among the very first organizations that proposed research on the use of networks of sensors, controllers and actuators to solve society scale problems such as health, disaster recovery, transportation systems, and education. Its mission is still very up-to-date as the EU intends to focus the FP VIII on societal problems. DEWS promotes interdisciplinary cooperation among researchers to achieve its research objectives. In particular, DEWS researchers are active in networked embedded systems automatic control, analog and digital electronics, computer science and telecommunications. DEWS has established strong research collaborations with some of the most prestigious universities in the world such as University of California at Berkeley, University of California at Los Angeles, University of Pennsylvania, Berkeley Wireless Research Center (BWRC), Berkeley Center for Hybrid and Embedded Software Systems (CHESS), Royal Institute of Technology (KTH) in Stockholm, and Cambridge University. Furthermore, DEWS signed at its inception a formal cooperation agreement with the University of California at Berkeley, involving the mutual exchange of researchers and students working on joint projects. DEWS has an ongoing collaboration with multinational companies such as Selex Communications (Chieti, Florence, Genoa, Pomezia), Thales Communications (Chieti), and Ford (Aachen, Germany). In this context, the Centre has been able to plan and manage projects of significant complexity as well as to spin-off an engineering company (WEST AQUILA http://www.westaquila.com/).

DEWS is participating in several industrial and European projects, in particular

- ***iFly*** project (STREP Project TREN/07/FP6AE/S07.71574/ 037180 “Safety, Complexity and Responsibility based design and validation of highly automated Air Traffic Management”) where the HYBRIDGE results on analysis and control of hybrid systems provide the basis for the study of advanced mathematical techniques for the development of autonomous flight (http://ifly.nlr.nl).

- ***MAREA*** project (WP-E SESAR, Eurocontrol "Mathematical approach towards resilience engineering in ATM") where the results achieved in the iFly Project provide the formal methodology to address the new SESAR 2020 concepts of operation, at present under study by the air traffic management systems' experts at EUROCONTROL

- ***ESSOR*** project (MP-IST-083-04 European Secure SOftware Radio programme) is a major European research program in SDR, supported by several nations and lead by major industrial manufacturers, whose main objectives are to strengthen European autonomy on a crucial technological area, federate European industries activities to support production equipments and support development of open standards

- ***aRoute*** project, the objective of the aRoute project, which has been proposed by DEWS with the strong partnership of WIND, Centro Ricerche FIAT and the University of Trento, is to define and develop a smart ICT platform for distributed and ubiquitous computing to be exploited in the domain of traffic sensing and control for low carbon multi-modal mobility

- ***IRMA*** project (with Thales Communications, Nationally funded by MIUR, L297) in the constant effort of improving capacity of wireless systems, ultra-wide band has been representing an interesting technique for providing large channel capacities, while allowing intrinsic support for flexible uncoordinated operations and robustness to channel impairments and interference

- ***PRESTO*** project (Artemis) aims at improving test-based embedded systems development and validation, while considering the constraints of industrial development processes

- ***VISION*** (FP7 "Ideas" Specific Programme - European Research Council Staring Grant Agreement, no.: 240555 - *VISION: Video-oriented UWB-based Intelligent Ubiquitous Sensing)* will develop an innovative infrastructure aiming at strengthening future wireless sensor networks (WSN) with the capability of supporting intelligent services for ubiquitous sensing, with particular emphasis on real-time 3D video sensing

- ***Precision agriculture*** project (Consorzio di Ricerca per l'Innovazione Tecnologica, la Qualità e la Sicurezza degli Alimenti, Nationally funded by MIUR) allows a detailed monitoring of environmental parameters which are critical for a particular cultivation enabling the optimization of production and the improvement of quality. At the same time through this monitoring it is possible to detect precisely pathologies or criticalities. As a result, an effective irrigation and a proper and selective dispensing of chemical treatments is possible, so lowering the presence of chemicals in foods while reducing costs

- ***Homeland security*** project (with Thales Communications, Nationally funded by MIUR, L297, art. 10) focuses on how the technologies of heterogeneous and cooperative wireless networks can provide a significant contribution in monitoring and control of land and/or sensitive perimeters. As an example the port areas are analyzed, recognizing that this peculiar scenario presents most of the challenging application domains of homeland security

DEWS was a member of the HYCON Network of Excellence (Hybrid control: taming heterogeneity and complexity of networked embedded systems, http://www.ist-hycon.org). It is currently a member of the Network of Excellence HYCON^2 (Highly-complex and networked control systems). The aim of these Networks of Excellence is to assemble a community of high-profile researchers involved in the broad area of hybrid system analysis and design with particular emphasis on distributed complex systems and industrial applications.

DEWS has created DEWSLab, a laboratory for the design and implementation of wireless sensor networks using products developed by Crossbow, a company headquartered in California. The lab has been configured as a "testbed" for innovative solutions related to routing and coding algorithms and it is used as a web service to allow remote access to interested parties. Within the Network of Excellence HYCON, DEWS has been chosen as the node of the European Embedded Control Institute (http://www.eeci-institute.eu/) for the realization of the European Networked Control Systems Laboratory (NCSlab).

The research activity at DEWS is structured into five research areas each including a number of research lines:

Methodologies and Technologies

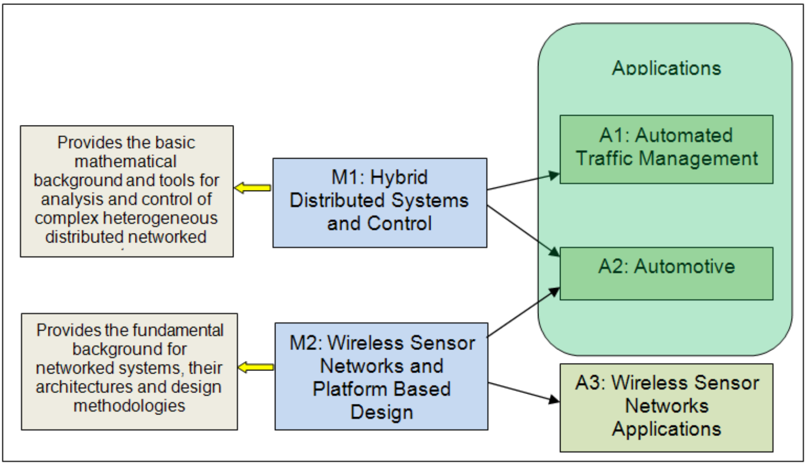
- M1: Hybrid Distributed Systems and Control
- M2: Wireless Sensor Networks and Platform Based Design

Applications

- A1: Automated Traffic Management
- A2: Automotive
- A3: Wireless Sensor Networks Applications

Research Areas M1 and M2 are foundational, they are aimed at developing new methodologies for the design of complex embedded systems and communication paradigms for their mutual interaction.

Research Areas A1, A2 and A3, instead, are orthogonal to the foundational areas, each covering an application specific research domain.



Networked Embedded Control Systems

Research Areas: M1, M2, A2, A3

Projects: HYCON, HYCON2

The growing interest in the research on Networked Embedded Control Systems is due to development of embedded systems and networked technologies. Embedded systems are computing system designed to perform one or a few dedicated functions often with real-time constraints.

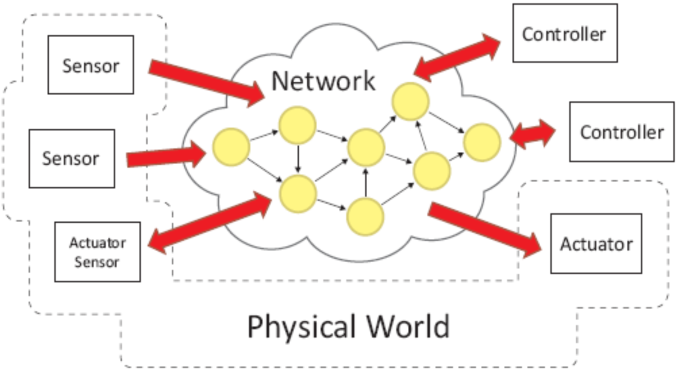


Figure 1: Abstract scheme of a
Networked Embedded Control System

They are embedded as part of a complete device often including hardware and mechanical parts. Today embedded systems span all aspects of everyday life, from automotive to avionics systems, from white goods to consumer electronics. The architecture of embedded systems has changed over the years as technological advances made it possible to integrate increasingly complex subsystems. In particular, it has become possible to coordinate different systems performing a particular function into delivering a global emerging behavior; for example, Unmanned Autonomous Vehicles (UAVs) are increasingly used in defense applications where they are called to fulfill missions that require close collaboration. Monitoring the environment, energy efficient buildings, and industrial plants is today possible with a possibly large number of sensors distributed over a wide region. In these applications, communication is an important feature. Given the operation they are called upon to perform and the physical locations where they are deployed, wireless communication has become an essential feature. Possibly the most advanced application of networked embedded systems is control. Industrial plant control and autonomous driving in freeways are typical examples of distributed embedded control. In these systems, sensors, actuators and computing elements are connected by means of a shared (wired or wireless) network as shown in Figure 1. Together with the opportunities offered by the wealth of sensing devices, by the communication devices and by the increasing computing power of control nodes, come tough challenges: control theory was based on abstractions that did not consider the non-idealities introduced by hardware and software devices, and by communication protocols. These effects pose a number of theoretical and practical problems that must be solved to advance the state-of-the-art in distributed control: stabilization, safety control, pole placement, Linear Quadratic Regulator (LQR), and other classical control problems must be cast in a different framework. When a control system is subject to non-idealities of the implementation platform and to communication constraints, operative systems and communication protocols have a direct effect on the design of the control policy and vice versa. Consequently optimal design for a distributed system must jointly address control, real-time computing, and communication protocol design. The expertise of the Center of Excellence DEWS on Networked Embedded Control Systems is recognized by all international academic and industrial partners of the Networks of Excellence HYCON and HYCON2. In particular, DEWS has been leader of the HYCON Work Package on Networked Control, and is currently leader of the HYCON2 Work Package on Networked Control Systems. There are four major projects that belong to this group: Analysis and Design of multi-hop Wireless Networked Control Systems, Symbolic Control, Mining Ventilation Control, and Vehicle Control.

Analysis and Design of multi-hop Wireless Networked Control Systems (M2, A3)

The increasing need to improve the efficiency of energy usage is pushing towards the design of green, energy efficient buildings eventually leading, to buildings whose net energy consumption is zero, as shown in Fig. 2. The term green building (also known as green construction or sustainable building) refers both to a structure and to the practice of designing structures that are environmentally responsible and resource efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. As a first motivation for this study we can state that buildings consume significant amount of energy. In fact buildings, both residential and commercial, account for approximately 20% of world energy use as depicted in Figure 3. Moreover, in a highly developed and industrialized country such as the United States, the shares of buildings in the energy consumption is even bigger reaching more than the 40% as shown in Figure 4.

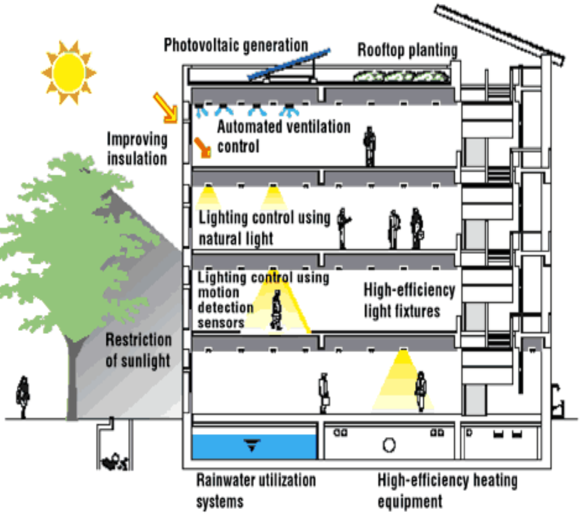


Figure 2: Example of a green building.

With growing environmental awareness and uncertainty in global energy markets, energy-efficient buildings hold great appeal for consumers, corporations, and government agencies alike. A second motivation for the research is that designing and deploying building control systems is becoming increasingly difficult. The design of future generation energy efficient buildings will rely on control algorithms that are capable of fine-tuning energy consumption.

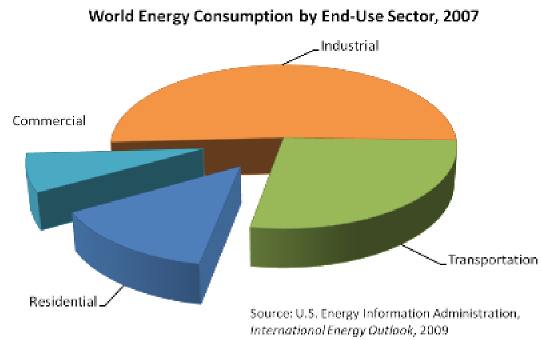


Figure 3: World energy consumption.

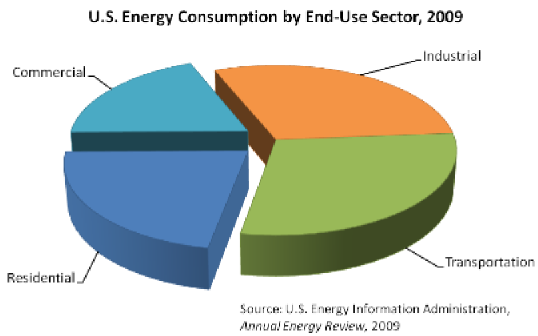


Figure 4: U.S. energy consumption.

Today, the design and installation of these complex electronic systems is based on experience from previous designs. Due to the scale and heterogeneity of control systems for large buildings, the design of the control algorithms and communication networks for these systems becomes very challenging and difficult to be carried out manually. In these smart buildings, Wireless (and Wired) Sensor and Actuator Networks (WSANs) determine the observable and controllable variables available to the building manager and have to be systematically designed, located and monitored to achieve effective control, diagnosis and reliability at low installation and maintenance costs. Wireless multi-hop networks plays a dual role in the realization of such intelligent buildings since, if on one side they introduce additional problems during design, on the other side they offer a rich palette of possibilities to the designer. In particular, multi-hop WSANs have very desirable characteristics for this application. Wireless multi-hop control networks are spatially distributed control systems where the communication between sensors, actuators, and computational units is supported by a shared wireless communication network. Control with wireless technologies typically involves multiple communication hops for conveying information from sensors to the controller and from the controller to actuators. The use of wireless networked control systems in industrial automation results in flexible architectures and generally reduces installation, debugging, diagnostic and maintenance costs with respect to wired networks. Wide deployment of wireless industrial automation requires substantial progress in wireless transmission, networking and control, in order to provide formal tools to quantify performance and robustness of a wireless networked control system. The design of the control system has to take into account the presence of the network, as it represents the interconnection between the plant and the controller, and thus affects the dynamic behavior of the closed loop system. Using a wireless communication medium, new issues such as fading and time-varying throughput in communication channels have to be addressed, and communication delays and packet losses may occur. Moreover analysis of stability, performance, and reliability of real implementations of networked control systems requires addressing issues such as scheduling and routing for real communication protocols. The main motivation for studying such systems is the emerging use of wireless technologies in control systems. While offering many advantages, the use of multi-hop networks for control is a challenge when it comes to predictability. The challenges in designing and analyzing multi-hop control networks are best explained by considering the recently developed wireless industrial control protocols, such as WirelessHART (www.hartcomm2.org) and ISA-100 (www.isa.org) as shown in Fig. 5. These standards allow designers of wireless control networks to distribute a synchronous communication schedule to all communication nodes of a wireless network. More specifically, time is divided into slots of fixed length and a schedule is an assignment of nodes to send data in each slot.

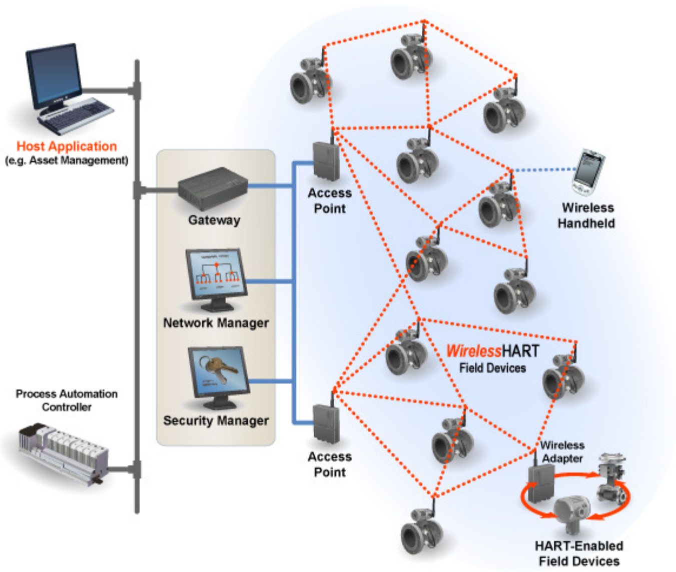


Figure 5: Device level architecture of the WirelessHART specification.

The standard specifies a syntax for defining schedules and a mechanism to apply them. However, the issue of designing schedules and routing remains a challenge for the engineers, and is currently done using heuristics rules. To allow systematic methods for computing and validating schedules, a clear formulation of the effect of schedules on control performance is needed. Motivated by these challenges, we proposed a formal modeling and analysis approach for multi-hop control networks a mathematical framework for modeling and analyzing multi-hop control networks designed for systems consisting of multiple control loops closed over a multi-hop (wireless) communication network, where we take into account the effect of topology, routing, and scheduling in the control performance. We proposed formal models for analyzing robustness of multi-hop control networks, where data is exchanged through a multi-hop communication network subject to disruptions. In order to design fault tolerant networked control systems, we exploited redundancy in data communication (i.e. sending sensing and actuation data through multiple paths) with the aim of rendering the system robust with respect to link failures (e.g. when the battery of a node discharges or a communication channel goes down), and to mitigate the effect of packet losses (e.g. transmission errors). We modeled redundancy, by defining a weight function that specifies how the duplicate information transmitted through the multi-hop network is merged, and by defining a semantics of the redundant data flow through the network. We stated necessary and sufficient conditions on the scheduling and routing of the communication network that guarantee to design a controller that stabilizes the plant dynamics. Moreover, we provided a methodology to design scheduling and routing of a communication network, in order to guarantee the existence of a stabilizing controller for any fault occurrence in a given set of failures configurations. An important feature of our approach is compositionality, namely it addresses the problem of designing scalable scheduling and routing policies for multiple control loops closed on the same multi-hop control network. When compared to the existing literature on Networked Control Systems, the research developed by the DEWS researchers in the HYCON2 NoE has pioneered the study of the controller design problem for multi-hop control networks that implement standardized scheduling and routing communication protocols, in order to enable co-design of controller, scheduling and routing.

Symbolic Control (M1, M2, A2, A3)

Discrete abstractions of continuous and hybrid systems have been the topic of intensive study in the last twenty years from both the control systems and the computer science communities. While physical world processes are often described by differential equations, digital controllers and software and hardware at the implementation layer, are usually modeled through discrete/symbolic processes. These mathematical models heterogeneity has posed during the years interesting and challenging theoretical problems that are needed to be addressed, in order to ensure the formal correctness of control algorithms in the presence of non-idealities at the implementation layers. From the synergistic collaboration of researchers in the control systems and computer science communities a novel and sound approach has recently emerged, which is termed “Correct-by-Design Embedded Control Software”. This research line can be roughly described as a three-step process, as shown in Figure 6, and detailed hereafter:

1. A finite state machine (or symbolic model) is firstly constructed, which is equivalent or approximates the continuous control system.

2. The original control design problem is solved at the discrete abstraction layer, on the symbolic model obtained.
3. The symbolic controller synthesized at the discrete layer, is appropriately refined so that it can be applied to the original continuous control system.

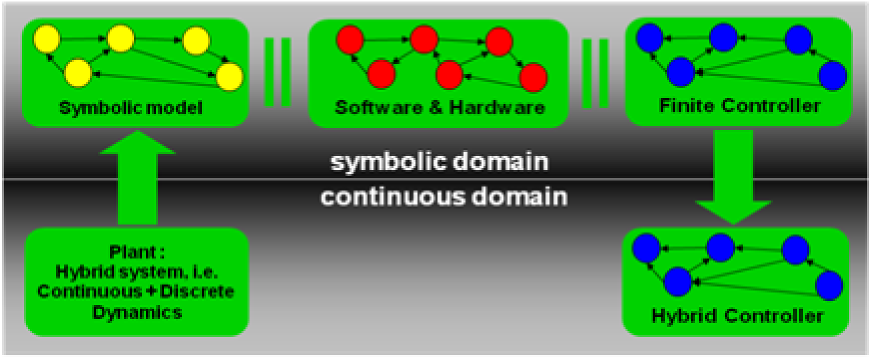


Figure 6: Correct-by-Design Embedded Control Software

The correct-by-design approach guarantees that controllers synthesized at the symbolic layer, enforce the desired specification on the continuous layer, with guaranteed approximation bounds. Moreover, this approach provides the designer with a systematic method to address a wide spectrum of novel specifications that are difficult to enforce by means of conventional control design paradigms. Examples of such specifications include logic specifications expressed in linear temporal logic or automata on infinite strings. The kernel of this approach resides in the definition and construction of symbolic models that are equivalent or approximate continuous and hybrid systems (Step 1 in the aforementioned methodology).

Several classes of dynamical and control systems that admit symbolic models have been identified during the years. We recall timed, multi-rate, rectangular automata, and o-minimal hybrid systems in the class of hybrid automata; controllable discrete-time linear systems, piecewise-affine systems and multi-affine systems, in the class of control systems. DEWS researchers have been active in this research topic and their collaboration with researchers from the University of California at Los Angeles (USA) and the Université Joseph Fourier (France) was fruitful, as demonstrated by the publications achieved in this research topic, as briefly summarized in Figure 7. The initial goal was developing a theory towards the definition and construction of symbolic models for the class of nonlinear control systems. We identified two key ingredients to accomplish to this ambitious goal: the notion of approximate bisimulation, introduced in 2007 by Antoine Girard and George Pappas, and the notion of incremental input-to-state stability introduced by David Angeli in 2002. We showed that these two key ingredients can be combined so that for any incrementally input-to-state stable nonlinear control system with compact state space it is possible to construct a symbolic model that approximates the original system with arbitrarily good accuracy in the sense of approximate bisimulation. This key result was than generalized to more general classes of continuous and hybrid systems, as follows.

First, nonlinear control systems affected by disturbances were considered. In this context an appropriate notion of approximate equivalence was introduced, which is termed alternating approximate bisimulation. This notion has been obtained by combining the notion of approximate bisimulation introduced in 2007 by Antoine Girard and George Pappas with the one of alternating bisimulation introduced in 1998 by Rajeev Alur and co-workers. This notion guarantees that control strategies synthesized on symbolic models, based on alternating approximate bisimulations, can be readily transferred to the original model, independently of the particular evolution of the disturbance inputs. In this regard, we showed that for any incrementally globally stable nonlinear control system affected by disturbances it is possible to construct a symbolic model which approximates the original system with arbitrarily good accuracy in the sense of alternating approximate bisimulation.

The results obtained for nonlinear control systems were then generalized to a class of hybrid control systems that is called switched systems. After generalizing the theory of incremental stability from nonlinear control systems to nonlinear switched systems we proposed symbolic models that approximate incrementally globally asymptotically stable nonlinear switched systems with arbitrarily good accuracy. The proposed theory was then tested on the Boost DC-DC converter, a benchmark selected within the Network of Excellence HYCON consortium.

The next research goal of DEWS researchers was to investigate further results which can ensure formal correctness of control algorithms in the presence of delays which are rather frequent in the exchange of information in distributed embedded systems. We therefore faced the problem of generalizing the results concerning the construction of symbolic models from the class of nonlinear control systems to the one of nonlinear time-delay systems. This generalization was not straightforward because time-delay systems are infinite dimensional systems. We first generalized the notion of incremental input-to-state stability from nonlinear control systems to nonlinear time-delay systems and provide sufficient conditions for checking this property in terms of Lyapunov-Krasovskii types dissipation inequalities. We then proposed first order spline-based approximation schemes to approximate the state of the time-delay system. The result achieved in this context mimic the one of nonlinear control systems in the sense that it shows that any incremental input-to-state stable time-delay system admits a symbolic model which is approximately bisimilar to the original system.

All the aforementioned results were based on a notion of incremental stability. In collaboration with researchers from the University of California at Los Angeles, we recently relaxed this assumption and showed that any incremental forward complete nonlinear control system admits symbolic models that approximate the original system in the sense of alternating approximate simulation. Incremental forward complete assumption is a rather mild assumption which is fulfilled for example by unstable nonlinear control systems.

The use of symbolic models for the control design of continuous and hybrid systems provides the designer with a systematic method to address a wide spectrum of novel specifications, that are difficult to enforce by means of conventional control design paradigms. In this context DEWS researchers faced the problem of designing symbolic controllers that enforce a nonlinear control system to satisfy a specification expressed in terms of automata theory on infinite strings and so that the interaction between the nonlinear control system and the symbolic controller is non-blocking. An explicit solution to this problem has been explicitly derived, resulting in the non-blocking part of the approximate parallel composition between the specification automaton and the symbolic model of the continuous system.

While being powerful, this approach often encounters some limitations in concrete applications, because of the large size of the symbolic models needed to be constructed in the implementation. Inspired by on–the–fly techniques for verification and control of finite state machines, DEWS researchers proposed efficient algorithms that integrate the construction of the symbolic model of the continuous system with the design of the symbolic controller. Our method provides substantial complexity reductions in most of practical cases, and we believe that it is one of the key ingredients to apply the "Correct-by-Design Embedded Control Software" research line to concrete and realistic applications.

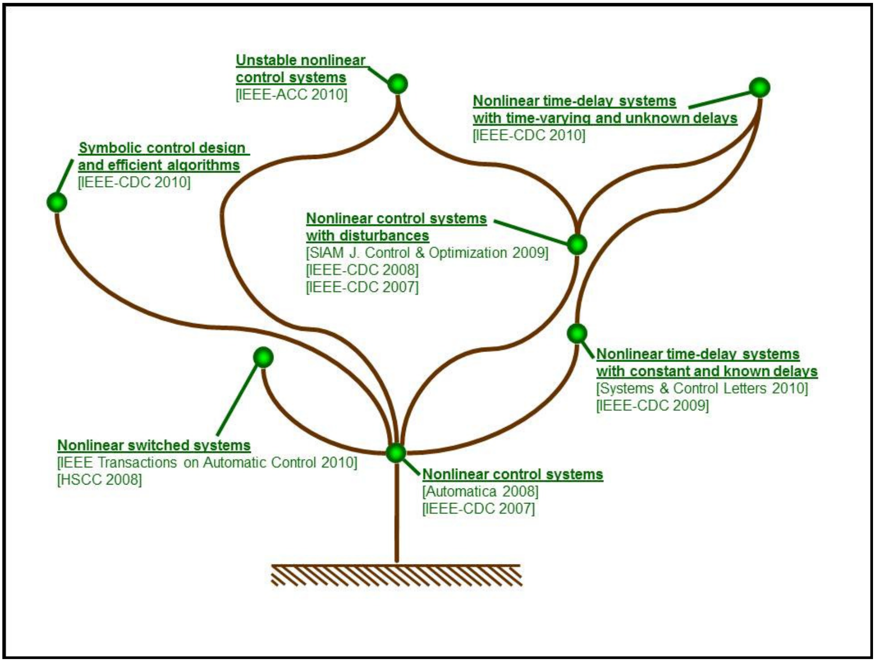


Figure 7: Correct-by-Design Embedded Control Software

Mining Ventilation Control (M2, A3)

In the context of the HYCON project, we conducted a research concerning ventilation automation on behalf of Boliden, a leading European metals company, using as test case one of its mines located in Garpenberg, Sweden (see Figure 8). At Garpenberg, polymetallic ore is mined. Its main constituents are zinc and silver, but the ore contains also lead, copper and gold. Overall, more than one million tons of ore are processed at the concentrator every year. One supporting process associated to ore extraction in a mine is the ventilation in tunnels, clearly needed for the oxygen supply of the personnel and for the combustion process of vehicles. Mining ventilation is an interesting example of a large scale system with high environmental impact where advanced control strategies can bring major improvements. More specifically, as much as 50% or more of the energy consumed by the mining process may go into the ventilation (including heating the air). Indeed, one of the first objectives of modern mining industry is to fulfill environmental specifications during the ore extraction and crushing, by optimizing the energy consumption or the production of polluting agents. The mine electric consumption was 4% of total industrial electric demand in the United States in 1994 (6% in 2007 in South Africa) and 90% of it was related to motor system energy. Another interesting figure is given in where it is estimated that the savings associated with global control strategies for fluid systems (pumps, fans and compressors) represent approximately 20% of the total manufacturing motor system energy savings. During a visit to the mine, we argued that re-configurability and wireless interconnection should have been key components in the design of an advanced ventilation control. Re-configurability is related to the variable topology of the mine (mobile process industry): after all accessible ore has been retrieved from a mine level, the extraction rooms are filled and a new level further down along the decline (which is a spiraling tunnel used by the trucks to reach the surface) is bored. All equipments, including the ventilation, have to be moved and re-configured in the new level. While making easier re-configurability, the necessity of wireless networks also derives from the blasting and drilling operations in the extraction rooms, rendering the wiring infeasible in these areas. Wireless networks can also be used for improving the efficiency of other processes that are of importance in operating a mine, e.g., equipment (trucks and ventilation system) maintenance, people and equipment localization, voice communication and security. As depicted in Figure 9, the actual control architecture is characterized by:

- no automatic control, but maximum ventilation power during ore extraction;
- no continuous monitoring of air quality;
- no wireless sensing;
- no localization system.

Figure 8: Mine site at Garpenberg, Sweden.

We proposed a wireless control architecture as shown in Figure 10, where we introduced networked sensors in the access tunnels and in the extraction rooms. The sensors placed in the access tunnels can make use of the existing wired connections, while those in the extraction rooms have to be wireless, due to the blasting activities. The exchange of sensor measurements and control signals can be then carried thanks to wired links as well as wireless communication.

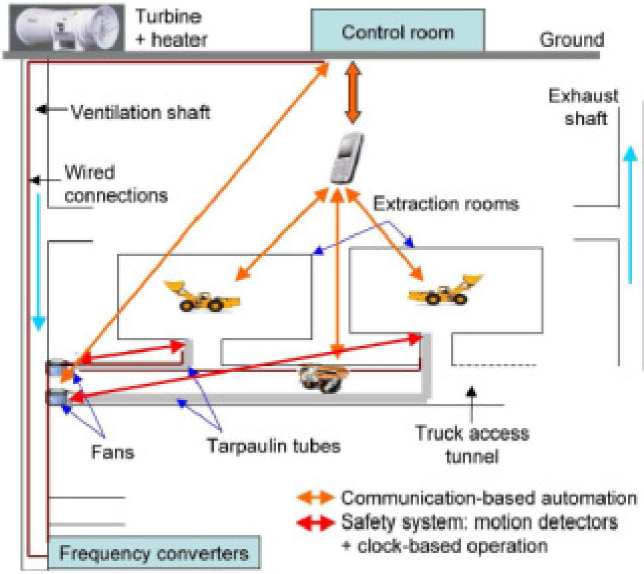


Figure 9: Mine ventilation process and actual control

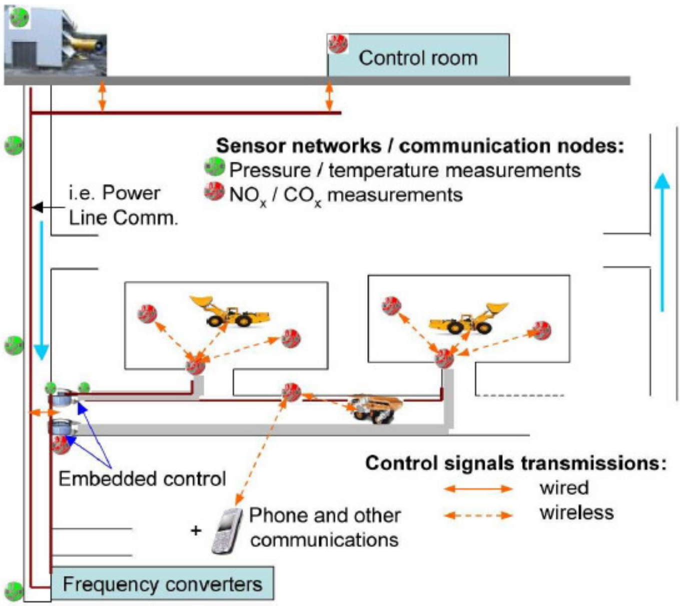


Figure 10: Proposed automation architecture.

The objective of the proposed control system is the regulation of turbine and heater to provide suitable air flow pressure at the ventilation fans in the tunnels, and the regulation of ventilation fans to ensure air quality in extraction rooms. We focused our attention on the control of air quality, addressing the following control specifications:

1. **Safety:** the gas concentrations cannot enter an unsafe set (a red alert zone), given by standard air quality for humans.
2**. Comfort:** the gas concentrations may enter, only for a bounded amount of time, an inefficient set (a yellow alert zone) where safety air quality for humans is satisfied but may be uncomfortable.

The non-idealities introduced by the multi-hop network are modeled by means of a communication delay. Inspired by an assume-guarantee reasoning, we considered a threshold controller, and modeled the closed loop system as a hybrid system. Because of the hybrid nature of the problem (e.g. number of trucks in an extraction room, continuous dynamics of the gas concentration and of the airflow model), it is extremely hard to exhaustively verify on the model whether the specifications above are satisfied for any discrete and continuous disturbance. To overcome these difficulties, we exploited abstraction techniques and model checking algorithms.

Vehicle Control (M1, A2)

In the past years, the development of an integrated philosophy has changed the way researchers and engineers design feedback devices in automotive control. With respect to some years ago, a much larger computational power has been made available to the control unit, due to the improvement of the electronics and to the increasing number of available customer features and technologies. This allows designers of automotive control systems to cope with a broader set of requirements and constraints.

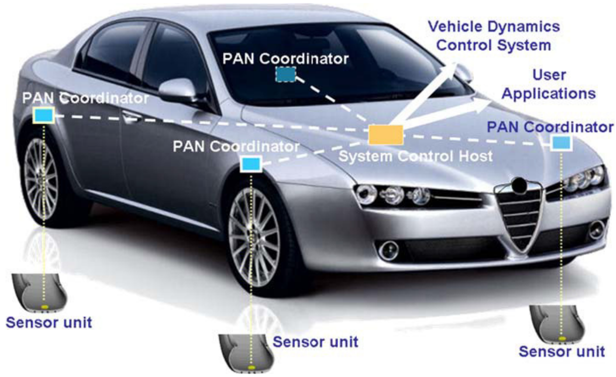


Figure 11: Intelligent tires for vehicle control.

Today's vehicles are equipped with many electronically controlled systems, whose integration is rising in complexity with the increasing number of available customer features and technologies. A way to solve the integration problem can be the introduction of a hierarchical control structure, where all control commands are computed in parallel in one core algorithm, and where the control has to take into account the interactions among the vehicle subsystems, driver and vehicle. The key element of integrated vehicle control is that the behavior of the various vehicle subsystems has to be coordinated, i.e. subsystems has to behave as cooperatively as possible in performing the desired vehicle functions. Clearly, the fully integrated controller will be more complex than the sum of the stand alone ones, but it will guarantee increased performance and robustness. Active Safety Systems Integration is one of the main research topics in vehicle control area. In order to maintain safe handling characteristics of the vehicle, several active system technologies (active braking, active steering, active differential, active suspension, etc.) have been developed. These devices modify the vehicle dynamics imposing forces or moments to the vehicle body in different ways and can now make use of smart sensors (for example, the so–called intelligent tires), allowing precise and distributed measurements from the environment, to increase the performance of the control action, the vehicle stability, the safety and comfort of the driver. On top of that, hierarchical and hybrid structures guarantee increased performance and robustness of control strategies, taking into account the interactions among vehicle, driver and environment, considered in parallel in one core algorithm. An important design factor to be considered in the standalone or integrated controller design is the actuator saturation, which limits the maximum obtainable performance. In an integrated control structure more power is available for control, thus potentially limiting the saturation occurrences. In all cases, it is important to manage critical situations, whenever actuators are not physically able to apply the required input. The use of "intelligent" (also called smart) tires with sensors that are embedded in the tread to provide direct tire strain measurements, allows precise measurement of friction, forces, load transfer, actual tire-road friction (kinetic friction) and maximum tire-road friction available, and hence increases significantly the efficiency of active safety systems. Currently, most of these variables are indirectly estimates using onboard sensors. With a more accurate estimation, we could even identify road-surface condition in real time. It also reduces realization costs, it increases flexibility, and it eases maintenance, debugging and diagnostics. The vehicle motion can be in general described as a rigid body moving in the free space, with 6 degrees of freedom, connected with the ground surface through tires and suspensions. This results in a model with high non–linear behavior and high coupling effects. As a further complication, these new technologies introduce problems regarding wireless communication, e.g., packet losses, fading effects, and synchronization losses. In this environment, an analytic approach and formal models that take into account all non-idealities that are typical of Networked Control Systems (NCSs) are needed. For the above reasons, we first addressed the vehicle control problem in a non-linear setting with ideal communication, and proposed an integrated controller to guarantee vehicle stability/trajectory tracking. We are currently introducing the non-idealities of the communication system in the control scheme derived in the ideal case. In particular, we are developing self-triggering control strategies that allow to trigger sampling and wireless transmission only when necessary, to prevent energy shortage. These research lines are pursed in the context of the HYCON2 project.

Air Traffic Management Systems

Research Areas: M1, A1

Projects: HYBRIDGE, iFLY, MAREA

In the last few years the trend in Air Traffic Management (ATM) systems research is to focus on airborne self-separation to yield less dense airspace. Typical examples of this trend are the research projects Mediterranean Free Flight and Advanced Safe Separation Technologies and Algorithms, funded by the European Commission. The research project “Safety, Complexity and Responsibility based design and validation of highly automated Air Traffic Management” (STREP iFly, 2007-2011) was funded by the European Commission in 2007 within the 6th Framework Programme. The Center of Excellence DEWS was one of the eighteen partners in the consortium, which included universities as well as industrial institutions. Project iFly aims at deploying the advanced formal methodologies developed in the project HYBRIDGE, funded by the European Commission in 2002 within the 5th Framework Programme, where the Center of Excellence DEWS participated as an academic partner. Currently, two approaches are pursued. One is to push for airborne self-separation which according to this view can safely accommodate traffic levels much greater than current en-route traffic. The other approach is based on the assumption that airborne self-separation cannot ensure safety in high density airspace. Both schools agree that airborne self-separation may be safe for airspace with sufficiently low traffic densities. From a research perspective point of view, this asks for evaluating at which air traffic levels airborne self-separation is safe. This is the main goal of the iFly project.

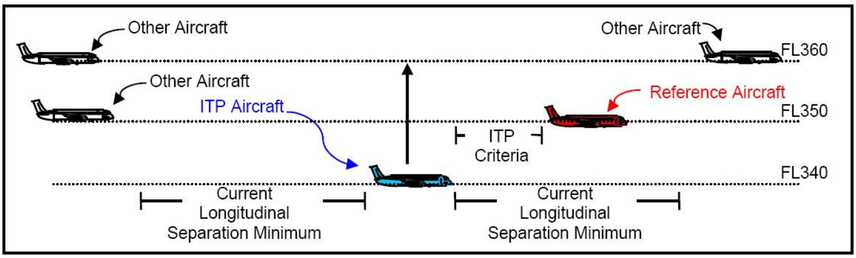


Figure 12. Airborne Separation In–Trail Procedure

In this project, our group proposed formal methods for the analysis of the so-called *multi-agent situation awareness inconsistencies*. Safety of ATM procedures requires that any agent has a correct perception of his situation as well as of the situation of the surrounding agents. Situation awareness inconsistencies of own and surrounding agents can lead to the execution of maneuvers that are unsafe and in some cases, even catastrophic. A formal approach to model and analyze ATM systems is very important. In particular, the complexity of ATM systems requires appropriate mathematical models that adequately capture key features of ATM systems. While aircraft dynamics are generally described by differential equations, pilots' and air traffic controllers' behaviors are well modeled by finite state machines, whose states and transitions mimic the procedure the agents are requested to follow. It is evident that a unique mathematical model for describing ATM systems needs to deal with both continuous and discrete dynamics. Hybrid systems' formalism, featuring both discrete and continuous dynamics, is characterized by an expressive power that we proved to be general enough to adequately describe ATM systems. Formal analysis of situation awareness inconsistencies arising in ATM scenarios can be well approached through the notion of *critical observability*. Critical observability is a structural property of hybrid systems that corresponds to the possibility of detecting if the current state of a hybrid system is in a set of critical states, representing unsafe, unallowed or non–nominal situations.

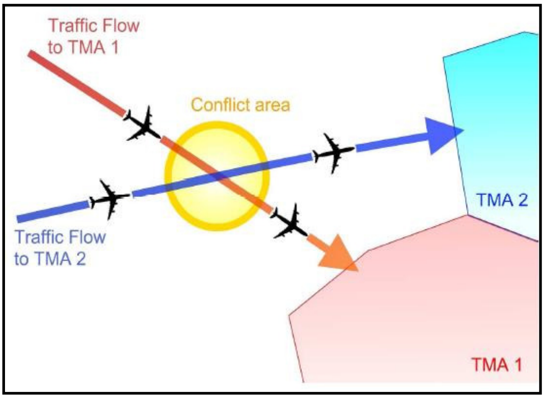


Figure 13. A3 ConOps Scenario

Researchers at DEWS introduced this concept in the control and hybrid systems community and proposed efficient algorithms for its verification. First investigations in this regard focused on critical observability of hybrid systems taken in isolation. However, when addressing the analysis of critical observability in ATM multi-agent scenarios, agents cannot be considered in isolation. Indeed, agents' interaction is responsible of the occurrence of unsafe situations that cannot be captured when considering different agents in isolation. For this reason, we proposed a compositional hybrid systems' framework that provides a formal model of the agents and a formal model of their interaction, as well. The interaction mechanism among the agents involved, has been modeled through an appropriate notion of composition that has been inspired by classical notions of parallel composition in automata theory and input–output composition for switching systems. This compositional hybrid systems' framework allowed us to formally approach the analysis of multi-agent situation awareness inconsistencies arising in relevant ATM procedures studied and under study in the ATM community. Although formally sound, this approach is applicable only with great difficulty to realistic ATM scenarios with a large number of agents. Indeed, the number of variables involved in realistic scenarios grows exponentially with number of agents, thus posing serious problems in the computational effort. For this reason we elaborated formal results which guarantee in many cases, a drastic computational complexity reduction which allows us to deal with ATM scenarios where an arbitrarily large number of the agents operate.

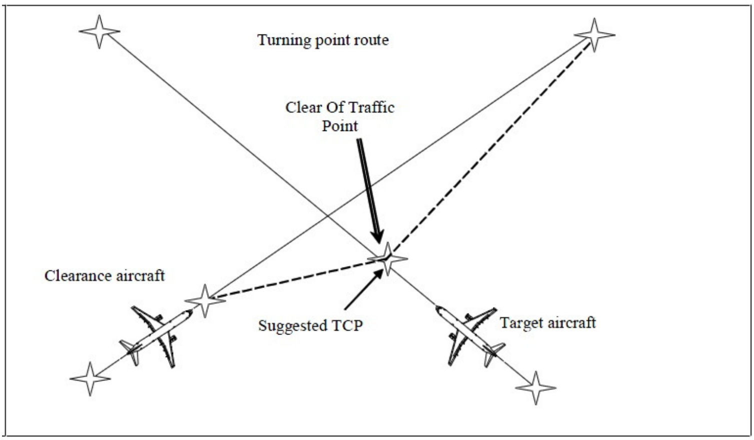


Figure 14. Lateral Crossing Procedure

We employed such a mathematical framework to model and analyze a number of procedures studied and currently under study by the ATM community, which include Airborne Traffic Situational Awareness In–Trail Procedure, Airborne Separation In–Trail Procedure (as illustrated in Figure 12), ASAS Lateral Crossing (as illustrated in Figure 14) and some scenarios within the Autonomous Aircraft Advanced Operational Concepts (A3 ConOps) (see Figure 13). The analysis that we carried out revealed the need for supplementary means, which can make the procedures under study critically observable. Our analysis also identified the weak steps of the procedures where additional alarm signals are needed in order to make the procedures critically observable.
The expertise of DEWS researchers has been essential in the success of the iFly project and motivated the iFly project coordinator to select the Center of Excellence DEWS, as the unique academic institution to join the ATM Project "Mathematical Approach towards Resilience Engineering in ATM" (MAREA). The MAREA project proposal has been submitted to the SESAR WP-E Projects Call. Among 43 projects proposals only 18 projects were funded. MAREA project was selected and started its research activities on March 2011.

Pervasive & Cognitive Wireless Networks

Research Areas: M2, A3

Projects: ESSOR, aRoute, IRMA

Mobile Ad-hoc Networks (MANET), Software Radio Technologies (M2,A3)

Software Defined Radio has become a reference technology in evolving wireless systems for advanced applications in communications and other civilian and military application domains. Many countries realize their national programs devoted to this area, expecting to achieve more capable and flexible radio systems, more effective in network centric operations. Most efforts are also dedicated in this field to achieve interoperability between different platforms, and the application domains often require auto-configuring and infrastructure-free operations that rely on MANET paradigms.

ESSOR is a major European research program in SDR, supported by several nations and lead by major industrial manufacturers, whose main objectives are to strengthen European autonomy on a crucial technological area, federate European industries activities to support production equipments and support development of open standards. The set of envisaged services to be provided in operation scenarios includes increased data and video transmission capacities, secure voice, database access and Internet-type IP services. These needs have to be satisfied while taking into account specific factors, for example, quality of service, end-to-end security and mobility management in the absence of any fixed communication infrastructure and in the presence of large mobility of nodes (MANETs). Proposed ESSOR architecture can be used as a common standard for projects realized by many countries. ESSOR results can be also a basis for further developments concerning more flexible and intelligent radios, leading towards network oriented Cognitive Radio. In the frame of its participation to the Consortium Radiolabs, Center of Excellence DEWS is heavily committed in the design, development and testing of a High Fidelity Simulator to be used for simulation and implementation of new waveforms defined within ESSOR. In particular, our research team has developed a design methodology based on the concept of meta-block, which is similar to the concept of meta-language. More precisely, the simulator consists of a set of functional blocks, each of which is obtained through a combination of four basic building blocks: a scheduler to handle events, an elaboration module to manage the stored events, and two blocks for IO Data management and storage. In this way the system can grow as a puzzle where every piece is configurable, synthesizable with different languages, and testable.

Besides the SDR approach, designing, developing and validating protocols for MANETs is one the most challenging fields in wireless systems and we have been involved in a quite large project funded by Thales Communications under a specific grant from the Ministry of Education and Research. In this frame we have developed a quite large laboratory testbed, that consists of an integrated environment that includes a simulation tool based on Omnet++, a scenario manager and a set of networked desktops that emulate simulation induced topology changes. The research work is progressing with testing of user applications and, more importantly, with the development of a realistic physical layer that includes cross-correlated fadings in a cooperative ad-hoc scenarios. This feature is supposed to enhance the typically poor description of wireless channels in the Omnet frameworks, while it is a paramount relevance to address the effect of wireless channels on topology management and networking functionalities of typical protocols (e.g. OLSR) in MANETs.

Pervasive cooperating communications and computing for multi-modal energy-efficient Eco-mobility (M2,A1)

The objective of the *aRoute* project, which has been proposed by DEWS with the strong partnership of WIND, Centro Ricerche FIAT and the University of Trento, is to define and develop a smart ICT platform (see figure below) for distributed and ubiquitous computing to be exploited in the domain of traffic sensing and control for low carbon multi-modal mobility. In particular, *aRoute* will allow

1) The pervasive real-time exchange of information in transportation systems through a heterogeneous wireless network that heavily relies on multi-mode

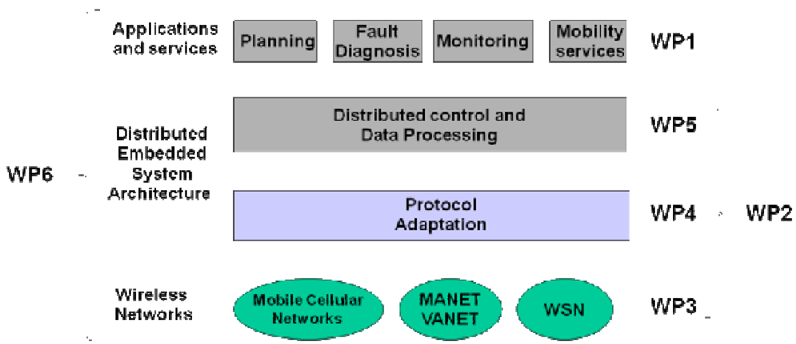
mobile devices and encompasses cellular mobile networks, inter-vehicular wireless networks, and wireless sensor networks;

2) The use of this information to enable monitoring of traffic density and energy consumption parameters, and to support local decisions of single agents to enhance the energy-efficiency and comfort of multi-agent systems, while reducing CO_2 emission and guaranteeing safety for users and operators in a multi-modal transportation system.

The platform is intended to integrate the research advances in specific areas that are necessary to support the *aRoute* goals. These specific areas are as follows:

- Hierarchical and distributed algorithms for multi-objective optimization in large scale networked control systems;
- Multi information fusion of land traffic related data on different levels,
- Cooperative and energy efficient communication in wireless networks;
- Design and cross-layer adaptation of networking protocols for meeting requirements of networked embedded systems;
- Open platform concept of distributed embedded systems architectures and smart middleware, which aims at the definition, design and development of algorithms and services for sustainable multi-mode mobility.

Implementation and experimental validation are included in the project and will be a fundamental step for the practical assessment of the platform with full engagement of the industrial partners of the consortium and the commitment of public administrations, who are interested in exploiting the *aRoute* results.



Ultra-Wide Band and flexible radio for integrated communication and positioning (M2,A3)

In the constant effort of improving capacity of wireless systems, ultra-wide band has been representing an interesting technique for providing large channel capacities, while allowing intrinsic support for flexible uncoordinated operations and robustness to channel impairments and interference. In particular, Impulse Radio (IR) is a particular form of Ultra Wide Band (UWB) technology that is characterized by the transmission of very short pulses occupying a large frequency bandwidth. This large bandwidth allows UWB signals to finely resolve multipath components and to exploit multipath diversity, thus making UWB a viable candidate for communications in harsh reference scenarios, such as industrial/factory indoor and forest/sub–urban outdoor environments. Moreover, due to their fine delay resolution properties, IR–UWB signals are potentially able to provide accurate ranging and synchronization capabilities. Key components for successful deployment of IR–UWB communication systems have been addressed during a years' long research at DEWS, with strong support and cooperation by Thales Communications in the frame of Project IRMA. Specifically, contributions have been provided in the following areas: 1) channel sounding and modelling in outdoor scenarios; 2) development and validation of robust detection techniques, e.g. those based on transmitted reference (TR) and autocorrelation receiver, and those based on differential rake receivers; 3) development of synchronization techniques for reducing the time of acquisition and the false alarm probabilities. Relevant results have been obtained in all three areas, and particular emphasis has been devoted to develop GPS-less localization techniques based on accurate ranging capabilities of UWB systems. Recent evolutions of this activity has led to define integrated positioning techniques, that resort to both UWB ranging and inertial sensors for accurate and reliable positioning by sensor fusion. Moreover, the exploitation of UWB for radio frequency identification (RfiD) with energy efficient transceiver has been addressed. Finally, cognitive networking has been addressed as a potential development in the frame of distributed and cooperative wireless sensing and communications.

Design Methodologies and Embedded SW Development

Research Areas: M2

Projects: PRESTO, VISION

The SW components within wireless pervasive networks assume a key role and require a specific and often disruptive approach with respect to the typical SW development and maintenance. This specific approach is called embedded software and in what follows two relevant projects dealing with it are illustrated: PRESTO and VISION.

PRESTO

The PRESTO project, which is funded by Artemis JU and will start on April 2011, addresses improvements on test-based embedded systems development and validation, while considering the constraints of the industrial development processes. This project is based on the integration of:

- exploitation of test-trace that are generated by test execution in the software integration phase carried out in common industrial practice to validate the requirements of the system;
- platform models;
- design space exploration techniques.

The expected result of the project is to establish a methodology based on functional and performance analysis and platform optimization at an early stage of the design development.

The PRESTO approach is to model the software/hardware allocation, by the use of frameworks, such as the UML profile for model-driven development of Real Time and Embedded Systems (MARTE). The analysis tools, including timing analysis including Worst Case Execution Time (WCET) analysis, scheduling analysis and possibly more abstract system-level timing analysis techniques will receive as inputs on the one hand information from the performance models of the HW/SW-platform, and on the other hand behavioural information of the software design from tests results of the integration test execution. Of particular novelty in PRESTO is the exploitation of traces for the exclusion of over-pessimistic assumptions during timing analysis: instead of taking all possible inputs and states into account for the worst-case analysis, a set of relevant traces is analyzed separately to reduce the set of possible inputs and states for each trace.

Particular attention will be devoted to industrial development constraints and in particular to:

- minimized cost in term of extra specification time and need of expertise;
- a simple use of the tools;
- a smooth integration in the current design process;
- a tool framework flexible enough to be adapted to different process methodologies, design languages and integration test frameworks;
- analysis results validated by confrontation with real platform results, and platform modelling for fast prototyping improved from this confrontation.

VISION

FP7 "Ideas" Specific Programme

European Research Council Staring Grant Agreement) no.: 240555
VISION: Video-oriented UWB-based Intelligent Ubiquitous Sensing

VISION will develop an innovative infrastructure aiming at strengthening future wireless sensor networks (WSN) with the capability of supporting intelligent services for ubiquitous sensing, with particular emphasis on real-time 3D video sensing.

One of the SW components of the project is the middleware distributed on each node that allows the implementation of intelligent services. The main contribution of DEWS is focused on this key element of the project, which is briefly described in what follows.

The requirements for high-quality video transmission cannot be easily guaranteed in a sensor field. The limitations in power supply and storage capability, and the necessity of keeping low the size, the complexity and the cost of sensor devices have up to now discouraged the provision of real-time video sensing services.
Design and management of distributed systems can be an hard task for developers because of their very heterogeneous and dynamic structure. A middleware approach could significantly simplify this task and it has been followed very often in the past. The main features of a middleware have been generally the following:

- *Marshalling/Unmarshalling*: data should be formatted to ensure hardware and software independence from hosts;
- *Data Representation and Codification*: the middleware protocol should define all type of data that the applications can manage;
- *Remote Invocation*: modern middleware should allow remote processing and method invocation;
- *OSI protocol compliant*: encoding and data preparation should not interfere with middleware protocol;
- *Location transparency*: the application should be able to communicate with all the devices composing the distributed systems by using the middleware capabilities;
- *Quality of services*: middleware is also suited to offer QoS to the application layer.

However, focusing on WSN the scenario is quite different. In fact, although middleware is well established research area in distributed computing systems, WSN poses new challenges because the traditional middleware techniques cannot be applied directly to WSN. In fact, most distributed system middlewares aim to hide the context, but WSN-based applications should usually be context-aware. Moreover, although many mobile computing middleware supports context-awareness, their major concern is how to satisfy the interests of single nodes. In contrast, WSN-based systems are data centric, reflecting the application goals. Also, WSN often use attribute-based addressing rather than relying on network-wide unique node addresses.

Finally, WSN requires the middleware to be lightweight for implementation in sensor nodes with limited processing and energy resources. In recent years, lot of work has been done on WSN middleware and several survey papers can be found in literature.

VISION will exploit the full system adaptability to the context as a ground-breaking approach to overcome these limitations. The dynamic QoS management, that is described in the next section, is possible thanks to a specific ultra-flexible middleware (MW) which links together all HW components of the system. The distributed middleware, represented by the dashed-line box, allows these components to participate in the process of optimally managing the resources based on the status of the context.

Wireless Sensor Networks Applications

Research Area: A3

Projects: Precision agriculture, Structural Health Monitoring, Homeland security, Home automation, Support to new arts

The methodological research activity and especially the one in M2 is strictly related to various application domains in which wireless sensors and actuators networks provide the key support for advanced applications. In particular, the following application areas are of interest for A3:

a) Environmental monitoring and control
b) Precision Agriculture
c) Wireless Networks in Manufacturing Plant
d) Structural monitoring
e) Homeland security
f) Home automation
g) Support to new arts

Although research activities have been done in all these areas, in year 2010 specific projects on the application areas "Environmental monitoring and control" has not been carried out.

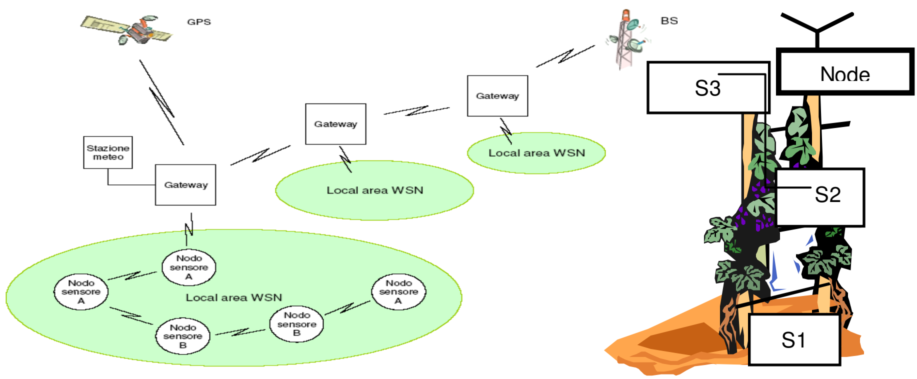
Besides all the activities to support the development of applications and prototypes, illustrated through the most recent projects in the remainder of this section, A3 has also animated international coordination activities on application domains of relevant interest. The COST Action IntelliCIS: "Intelligent Monitoring, Control and Security of Critical Infrastructure Systems" falls in this context and is summarized below.

The main objective of the Action is to develop innovative intelligent monitoring, control and safety methodologies for critical infrastructure systems, such as electric power systems, telecommunication networks, and water distribution systems. This is an interesting action, that brings together expertise from different field in order to develop methods for managing and protecting critical infrastructures, especially those of major interest for the

society.
DEWS is especially committed in WG3, which deals with telecommunications networks and is particularly targeted to i) Investigate security models as they apply to various networks (e.g., wireless, optical), ii) design methodologies for intelligent management, monitoring and control of communication systems, iii) Develop network security models and use them to enhance network security, iv) develop resource allocation and Quality of Service provisioning methodologies, v) investigate similarities and connections with transportation systems. DEWS is contributing with original work on developing and implementing security mechanisms in wireless sensor networks (see internal project WINSOME), and on designing routing and topology control for wireless networks in critical applications.

Precision Agriculture

A detailed monitoring of environmental parameters which are critical for a particular cultivation can permit the optimization of production and the improvement of quality. At the same time through this monitoring it is possible to detect precisely pathologies or criticalities. As a result, an effective irrigation and a proper and selective dispensing of chemical treatments (e.g. fungicides) is possible, so lowering the presence of chemicals in foods while reducing costs. In this report the project entitled "Monitoring technologies for the support of cultivation of grapevine and the production of wine" is briefly described.



The impressive development of Internet of things will allow to connect with an ever increasing continuity and reliability sensors and actuators to local area networks and, through them, to convey the data to potentially around the world. In such a context a crop can be equipped with networks of sensors/actuators, and through their administration by the farmer, it is possible to make maximally efficient the agricultural production, allowing to the production to reach quality objectives otherwise difficult to achieve. One area of agricultural production in which this kind of methods are being tested for some four years is the cultivation of vines for the production of high quality wine. In this context networks of sensors/actuators (often wireless) have been deployed in Italy (Chianti area) and in France, collecting statistical data showing that a proper use of these innovative technologies can lead to increases in production capacity and in product quality. However, it is straightforward that these actions have focused on experimental areas that historically operate in the wine sector, with internationally recognized expertise and results. Indeed, to produce quality wine we can not rely solely on technology but it must be accepted by those who holds the know-how and dominates the complex and delicate process of high quality wine production, so that the technology exploitation can be maximized. In this project the equipment of a vineyard with networks of sensors that collect a series of chemical and microclimatic parameters and which make such data available to growers is proposed. This will make it possible to provide to professionals in that sector, which already have significant expertise and sensitivity in managing the process of cultivation and production, a new tool that enables them to further improve the quality of their product, reducing costs and preserving the environment. Monitoring in this context aims a number of objectives: (i) improvements in productivity, (ii) improved quality, (iii) optimization of resource use (e.g. water), (iv) minimization of 'environmental impact (use of pesticides, herbicides, etc.), (v) lower costs (automation of operations, optimization of interventions). To be most effective, monitoring the weather should be performed on two different spatial scales: (a) macroclimatic or meteo monitoring , which measures the weather of the entire cultivated area, (b) microclimatic monitoring, which performs measurements at much shorter distances and with a spatial resolution much higher in the cultivated area. Each crop has special monitoring requirements, related to the different sensitivity of individual plant species to various climatic parameters and the specificity of the threats caused by them. Viticulture, as a first phase of the wine production process, is one of the crops most valuable in terms of economics in general in Italy and in the Abruzzo region. The specific requirements for monitoring applied to winemaking can be summarized as follows.

Macroclimatic monitoring - integrated monitoring of: (a) air temperature, (b) direction and speed of wind, (c) rainfall intensity; in order to: (i) report in near real time the approaching of frosts, (ii) create statistical maps of the risk of icy conditions, (iii) create historical maps of macroclimatic conditions for the preparation of estimates of the maturation process and the addressing of harvesting operations (quality improvement), (iv) develop estimates of the amount of water fallen on the cultivation in order to manage selectively watering operations (optimization of resources) and make assessment of the risks associated with excessive release of water.

Microclimatic monitoring - integrated monitoring of: (a) solar radiation, (b) humidity, (c) soil moisture, (d) moisture of the leaves, (e) soil pH, (f) concentration of CO in air, (g) concentration of iron in the soil (h) concentration of herbicides in soil.

There are several classes of end-user that might be interested in the type of information that can be extracted from the base of raw data collected. Among them there are farmers, associations and public agencies operating in the agrifood industry sector, public bodies operating for the protection of health, and organizations concerned with intellectual property protection.

Distributed network architecture for the monitoring system

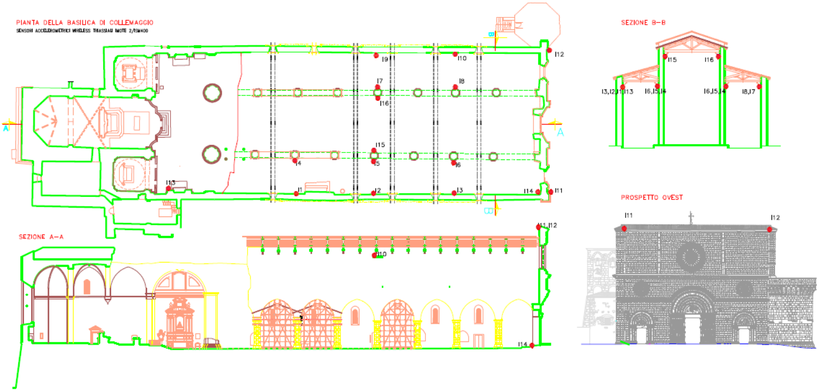
The advanced features of a monitoring system, both in terms of richness of information acquired in the environment and of timeliness in the development and delivery to a user, can not disregard the availability of a capillary communications network. For ease of installation, maintenance and reconfiguration, the network must necessarily make use of wireless technologies. In this context both short-range communications systems (e.g. Wireless Sensor Networks, WSN, and solutions for radio frequency identification - RFID) and systems that provide connectivity on a geographic scale (e.g. mobile systems) are available. The combination of these network components, together with the use of proper protocol solutions (e.g. self-configuring networks and with low energy consumption on some nodes) and of advanced software architectures (embedded operating systems, distributed databases, localization features) leads to the definition and advanced implementation of service platforms characterized by: i) modularity, ii) flexibility, iii) sustainability, iv) pervasiveness, v) ease of usage and of maintenance. All these functions are largely absent in traditional monitoring systems. Based on these considerations, in this project the network architecture for wireless coverage of a cultivated area consists of wireless sensor nodes for the pervasive monitoring , each affiliated with one (or more) gateway(s). The measuring stations must be differentiated, ie equipped with different configurations of sensors optimized according to the measuring point, in order not to unnecessarily increase the complexity and cost of each station. Gateways should be able to organize a network among themselves so as to ensure the transport of data collected through the cultivated area up to the first point of access to the infrastructured communication network. With regard to the WSN network component, it can be reviewed as a set of homogeneous elements, whose goal is mainly to collect data useful for environmental monitoring. The distance between adjacent nodes can vary from a few tens to a few hundred of meters (depending on the technology and on the requirements of energy autonomy of individual nodes). In such networks there is a BaseStation, that is an element that is responsible, on a local basis, of the collection, storage and processing of data collected by sensor nodes in the interested area to make them accessible to an infrastructured network, which is in turn responsible onward transmission to the remote control center. The sensor nodes are equipped with an interface with the whole range of planned sensors and they have to manage sampling in accordance with the physical quantities under observation. It is also necessary to equip sensor nodes of software modules that can implement the geographic positioning of nodes, which allows to tag collected data with their coordinates for the purpose of enable targeted activities. This is particularly important in the "precision farming" which aims to optimize the interventions (irrigation, fertilization, pest control, harvest) planning in a geographically selective mode all operations on the basis of data provided by the monitoring system. The ability to automatically obtain the location of the nodes can make the network deployment easier and cheaper, especially in those cases where the system must be moved periodically as affected by crop rotation in soils.

Upon completion of the technological framework provided in the preceding paragraphs, it is interesting to consider the use of RFID for traceability in food processing field, with the aim of responding to the needs of:

- checks to ensure local and typical productions (geographical area protected designation of origin etc.);
- anti sophistication checks.

Therefore, in this scenario , cultivation is the first step in a transformation process (e.g. grapes into wine and derivatives) which coincides with the path to be traced. The most basic tracking application should provide for the labeling of the harvest with a tag that identifies the source and allows you to automate the tracking operations that follow the raw material, including information from more diverse farms along the different stages of the chain processing or distribution. An evolution of this basic application may leverage the added value brought to the agricultural production activities from the monitoring system described in the preceding paragraphs, one of the peculiarities of the environmental monitoring is indeed its capability to assess the quality of production, linking it to the environmental conditions which accompanied the process of maturation.

Structural Health Monitoring



Structural health monitoring systems have a key role in building maintenance and their post-disaster assessment. Traditional systems are made up of grids of sensors deployed along the building and communicating with a central processing unit via a cable connection. In the last years, Wireless Sensor Networks (WSN) emerged as a possible attractive alternative solution. In facts, the replacement of cables with wireless connections along with the use of modern sensors allows to obtain significant benefits in terms of cost, size, ease of installation and invasivity (key issue in the case of historical buildings).
From the network hierarchy viewpoint, sensor nodes measure the structural response and send their data to a so-called "sink node", which collects all data from the whole network. Modern sensor nodes have limited maximum power at the antenna (owed to technical and economic requirements), so the available radio range may often end up to be under-dimensioned for the structural monitoring of large constructions; however, thanks to multi-hop routing techniques, connectivity can be extended well beyond the radio range of the single transceiver. The sink node usually forwards received data towards

external networks (it plays the role of a gateway). This network unit will be connected to a public network (e.g. to the public land mobile network through the GPRS data service) in order to allow the forwarding to the query messages to the sensor network and to gather the data collected.
Our first goal is to exploit the potential of this paradigm for the implementation of an efficient monitoring system. One of the most representative building of the city of L'Aquila, the Basilica of Collemaggio, will be the first challenging scenario we are going to face. In it, we will try to take advantage of all the features mentioned above, creating a system able to efficiently acquire and transmit data.
Our research activity will then be oriented to the optimization of data processing. First of all we will try to implement a distributed processing within the network: the development of appropriate techniques for distributed computing, will allow to exploit the processing capabilities of the nodes in order to obtain a local data processing. Besides an optimization of the communication (and therefore of energy consumption), the distribution will be the first step towards a real-time processing of data.
As is well known, one of the major limitations of wireless motes are the limited performances. Therefore, our idea is to use configurable hardware devices (e.g. FPGA) for the creation of hw/sw mixed service based architecture, with processing services directly implemented in hardware. In practice, we want to combine the mote processor with a set of ad-hoc developed co-processors specifically designed for the implementation of various processing modules.
The final result will be an efficient monitoring system able to support heterogeneous services. This result is very important, because in the medium to long term we intend to address three of the major current challenges of civil engineering: structural model updating, damage detection and seismic early warning.
A monitoring system that allows accurate measurements could be the basis for an efficient model updating action. This is extremely important for structural design: only the gradual correction via experimental data allows to obtain a truly reliable model.
The ability to get a long term monitoring action, combined with the integration of environmental effects correction techniques, will allow to implement appropriate damage detection mechanisms. In this way it will be possible to characterize the state of buildings and implement appropriate preventive action with regard to seismic risk.
Finally, the major challenge will be to take advantage of smart sensors for the implementation of seismic early warning mechanisms. In a single-station local

approach, our goal is to specialize some of the network nodes as sentinels that will be able to raise an alarm in few - but often vital - seconds before the arrival of high energy seismic waves. This will be the basis for the development of efficient emergency management mechanisms (e.g. automatic security procedures for hospitals, data centers, power plants, gas distribution network ecc.).

Homeland security

Maximum attention is paid to the issue of homeland security and, in particular, on how the technologies of heterogeneous and cooperative networks can provide a significant contribution in monitoring and control of land and/or sensitive perimeters. As an example you can refer to the port areas, recognizing that this scenario presents most of the typical application domains of homeland security.

Indeed, in a port area the following needs, sometimes mutually dependent, are present:

a) to secure the port area inside and around its perimeter, which has a part on the sea and a part on the ground and which provides, respectively, the transit of vessels, vehicles and people;

b) to enable the safe harbor activities, often dangerous being characterized by the coordinated movement of vessels, objects and vehicles;

c) to minimize emissions into the atmosphere and water in order to reduce the environmental impact;

d) to increase the efficiency of logistics management;

e) to activate measures aimed at reducing the phenomenon of counterfeiting and smuggling of goods.

Each of the above application contexts is characterized by specific rules and, in this framework, is open to the use of innovative technologies. To prove the topicality of the issues outlined above and the urgency to deal with it is useful to mention the project Imcosec (Improve the supply chain for container transport and integrated security Simultaneously - www.imcosec.eu), started on 1 April 2010, which the EU has entrusted the task to identify and describe gaps in security and efficiency of transport logistics. The project is funded through the 7th European Framework Programme (FP7) and brings together different agencies, including the BIC (Bureau International des Containers) and, for Italy, the Politecnico di Milano, and will propose processes, procedures and technologies to help to smooth the transport chain between a port and its hinterland. The first objective is to draw a road map that allows to carry out demonstration activities of the efficiency of the proposed solutions.

The specific aim of this project is to maximally exploit wireless technologies to increase efficiency and resiliency of security related systems and functionalities in this challenging scenario.

Home automation

The aim of "Casa+" project is to help people with Down syndrome to get their own autonomy by increasing the awareness of their means and always keeping the safety. To achieve these goals we will assist those people with technological support in doing the every-day actions in and outside the house. The plan is to give to the house itself the ability to control and help its guests by using some devices able to check lighting system, water system, ect, and to interact with people living in the house. The project is totally consistent with the Sue Buckley research fund vision (http://www.sue-buckley.org/):*"Our vision is a world where all young people with Down syndrome are offered the opportunities that they need to achieve their individual potential..."*

All projects' activities can be subdivided into three main categories:

Home Living:

We want to help guests to use the house's facilities in the best way, in order to do this we need to localize each guest in the house and customize the house action to the particular user. Just to give an example: if someone gets out of a room without switching off the light, the house will remind the guest, calling with is name, that if there is no one left in the room there is no need to keep the light on, and if the user doesn't get the message, than the house takes care of it.

The project also plans to help guests in cooking providing an interactive cookbook that will guide them through the recipe giving the needed actions and timing.

Communication:
The house has two multi touch computers installed. By using these devices guests can surf the web though a scalable and customizable browser and also share with each other their multimedia contents such as photos, movies, songs, etc.

Follow Me:
This is about a tracking system, made though a specific device or a smartphone, with geo-fencing capabilities. Thanks to a web interface it is possible to define a safe area/path and since the user stays in this area no one is aware of its position. As the user goes out of the safe area, its position is shown on the web interface and an alarm message is sent to the assisting personal. The user can also call the assisting personal in case of emergency by pressing an alarm button.

The project will provide new tools based on ICT technologies that could enable the completion of existing educational protocols or activate new ones.

The expertise of DEWS in the field of home automation, in particular regarding heterogeneous wireless sensors/actuators networks, is proving to be essential for the CASA+ project.
This ability to introduce interesting new elements in the context of home automation through a wise insertion of wireless components is also a key element of a recently funded project, aiming at innovating the home automation context, entitled SMILING (SMart In home LIviNG: Innovative technologies for sensing and automation in Home Automation).
The project aims at creating a "laboratory" for the transfer from research to the industries involved in developing technologies of advanced automation and sensors, in the field of home automation. These technologies will allow the development of innovative products and the delivering of new services to improve housing quality and energy efficiency of homes. The laboratory will consist of three operating units distributed in south-central Italy. The coordinator will be in the Marche area (Fabriano, AN), while other places involved will be located in Abruzzo (L'Aquila - DEWS) and in Campania (Napoli). The two involved universities, Università Politecnica delle Marche, as leader, and Università degli Studi dell'Aquila - DEWS, will provide its expertise and research findings in order to upgrade the product offerings of many SMEs in those territories that are currently operating in the fields of mechanics, electronics, mechatronics, information technology, furniture and systems for energy production and management. The distributed laboratory will perform three main functions: will serve as a demonstrator of the innovative proposals coming from the involved research centers, will stimulate and support, in both technical and management levels, the creation of new high tech enterprises, and will be support new enterprises in carrying out tests and as a meeting and exchange point.

Support to new arts - RF Sounding: a System for Generating Sounds from Spectral Analysis

The contamination between scientific knowledge and artistic components is too often limited to chance, mainly stemming from the convergence on the same research group of technical and artistic interests. In this scenario we are mainly interested in the integration of wireless communications and audio waves, being both characterized by the same propagation medium, even if with substantially different propagation modes.

RF Sounding is an open space installation which comprises both artistic and technological innovations; its aim is to provide the user, while entering a specifically defined area, with awareness of radio frequency signals characterizing the cellular networks band. Indeed, radio signals are shifted, with proper elaboration, to the audible band and the result is spread all over the specific area through a certain number of loudspeakers.

For this procedure we have been inspired by the eternal metaphor of the impossible human dream to fly, thus the limitations of our senses which are capable of feeling audio waves (sounds) but (maybe luckily) are not capable of directly feeling radio frequency (RF) waves are highlighted. The translation is the starting point for a more complex and exciting musical composition.

The aim of this project is twofold. Indeed, from one side we want to increase end users knowledge of the strength of the power emitted by their cellular phones with respect to the electromagnetic fields produced in the environment, on the other hand we want to provide for an artistic and interactive installation that can also be remotely joined through a web interface.

The main project comprises a hexagonal area that is equipped with gate sensors, a subwoofer, six loudspeakers, a receiving antenna for RF sensing and six sensor nodes for localization. The RF signals gathered by the antenna and the localization data coming from the sensor network are sent to a spectrum analyzer and an elaboration unit in order to process sound and spatialization algorithms (see Fig. 15 and Fig. 16).

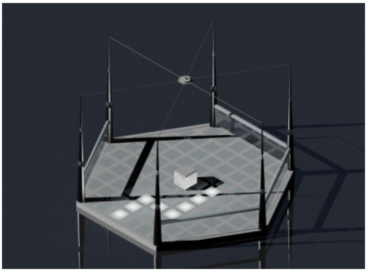


Fig. 15. RF Sounding: axonometric view

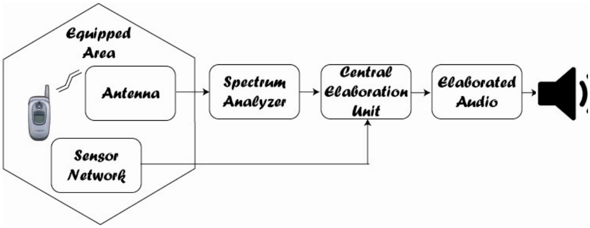


Fig. 16. RF Sounding: dataflow diagram

A first prototype has been successfully realized and presented as full paper and demo to various international scientific conferences. It has been also approved by various Italian contemporary music composers. With respect to the general project the spectrum analyzer is replaced by a GSM engine (Siemens TC35), the localization algorithm is achieved through an active target and sound spatialization is simplified in stereophony.

The active localization is achieved through the use of Crossbow Crickets and a proper developed algorithm. These nodes establish a network where a certain number of anchors (called Beacons) send to a Listener (the node to be localized) both RF and an ultrasonic signals. By computing the time difference of arrival of the two signals, the Listener is able to estimate its distance from each Beacon.

The sound produced by loudspeakers is depending on BSs channel frequencies and Rx powers, as well as user position in space. The sound is elaborated in real time on a laptop that receives data from the listener and the TC35. A proper implementation of Open Sound Control (OSC) protocol has been developed to guarantee these connections. Since we want to represent the different perspectives of reality that can be enjoyed only by flying, the demonstration space is divided into small spaces (corresponding to possible user's positions and thus perspectives) and for each of these positions short musical pieces are developed. They differ from one position to another only for a certain sound characteristic (e.g. timbre) and the larger the distance between two points, the higher the difference between the pieces. Moreover, each piece of music lasts for no more than 30 seconds and can be smoothly interrupted by moving from one position to another. It also moves from the additive synthesis of RF signals (translated to the audible band) to a more complex and changing sound by the exploitation of variables evaluated by means of localization data (distance, speed, permanency, etc.). A proper use of some resonant filters (with moving formant) as well as frequency modulation technique and randomicity assures the completeness of each single micro-piece.

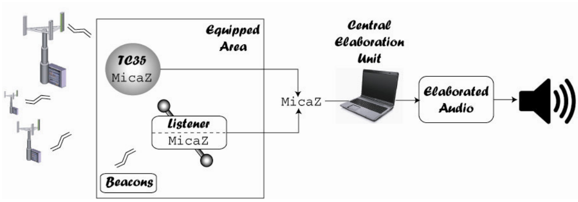


Fig. 17. Dataflow of the realized prototype

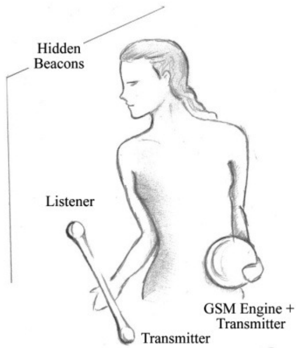


Fig. 18. Prototype from users point of view

Publications

2010

1. D. Bianchi, A. Borri, G. Burgio, M.D. Di Benedetto, S. Di Gennaro, Adaptive Integrated Vehicle Control using Active Front Steering and Rear Torque Vectoring, International Journal of Vehicle Autonomous Systems, Special Issue on: "Autonomous and Semi-Autonomous Control for Safe Driving of Ground Vehicles", Vol.8, No.2/3/4, pp.85-105, 2010
2. D. Bianchi, L. Rolando, S. Onori, L. Serrao, G. Rizzoni, N. Al-Khayat, T. Ming, H. Pengju Kang, A Rule-Based strategy for a series/parallel hybrid electric vehicle: an approach based on dynamic programming, ASME Dynamic Systems and Control Conference, Marriott Boston Cambridge September 13-15, 2010 Cambridge, Massachusetts
3. S.D. Bopardikar, A. Borri, J.P. Hespanha, M. Prandini, M.D. Di Benedetto, Randomized Sampling for Large Zero-Sum Games. Proc. of 49th IEEE Conference on Decision and Control, Atlanta, USA, December, 2010
4. A. Borri, G. Pola, M.D. Di Benedetto, An Integrated Approach to the Symbolic Control Design of Nonlinear Systems with Infinite States Specifications, Proc. of 49th IEEE Conference on Decision and Control, Atlanta, USA, December 2010, pp 1528-1533
5. B. Castillo-Toledo, S. Di Gennaro, Stabilization for a Class of Nonlinear Systems: A Fuzzy Logic Approach, Engineering Applications of Artificial Intelligence, Vol.23, pp.141-150, 2010
6. B. Castillo-Toledo, S. Di Gennaro, G. Sandoval Castro, Stability Analysis for a Class of Sampled Nonlinear Systems with Time-Delay, Proceedings of the 49th IEEE Conference on Decision and Control, Atlanta, USA, 2010
7. E. De Santis, M.D. Di Benedetto, G. Pola, A complexity reduction approach to detectability of switching systems, International Journal of Control, 83(9):1930-1938, September, 2010
8. M.D. Di Benedetto, G. Di Matteo, A. D'Innocenzo, Stochastic Validation of ATM Procedures by Abstraction Algorithms. ICRAT 2010, June 02-03, 2010
9. S. Di Gennaro, J. Rivera, B. Castillo-Toledo, Super-Twisting Sensorless Control of Permanent Magnet Synchronous Motors, Proceedings of the 49th IEEE Conference on Decision and Control, Atlanta, USA, 2010
10. P. Di Marco, P. Park, C. Fischione, K.H. Johansson, TREnD: a timely, reliable, energy-efficient dynamic WSN protocol for control application.

IEEE International Conference on Communications – ICC, May 23-17, 2010. Cape Town, South Africa
11. P. Di Marco, P. Park, C. Fischione, K.H. Johansson, Analytical modeling of IEEE 802.15.4 for multi-hop networks with heterogeneous traffic and hidden terminals. IEEE Global Communications Conference – GLOBECOM, December 6-12, 2010. Miami, Florida
12. M. Di Renzo, D. De Leonardis, F. Graziosi, F. Santucci, Timing Acquisition Performance Metrics of Tc-DTR UWB Receivers over Frequency-Selective Fading Channels with Narrow-Band Interference: Performance Analysis and Optimization, IEEE Military Communications Conference, October 31 - November 3, 2010, San Jose, CA, USA
13. M. Di Renzo, M. Iezzi, F. Graziosi, Beyond Routing via Network Coding: An Overview of Fundamental Information-Theoretic Results, IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, September 26-30, 2010, Istanbul, Turkey, (invited paper)
14. M. Di Renzo, F. Graziosi, F. Santucci, A Comprehensive Framework for Performance Analysis of Cooperative Multi-Hop Wireless Systems over Log-Normal Fading Channels, IEEE Transactions on Communications, Vol. 58, No. 2, pp. 531-544, February, 2010
15. M. Di Renzo, F. Graziosi, F. Santucci, Channel Capacity Over Generalized Fading Channels: A Novel MGF-based Approach for Performance Analysis and Design of Wireless Communication Systems, IEEE Transactions on Vehicular Technology, Vol. 59, No. 1, pp. 127-149, January, 2010
16. M. Galicia, B. Castillo-Toledo, A. Loukianov, S. Di Gennaro, J. Rivera, Discrete Time Sliding Mode Torque Control of Induction Motor, Proceedings of the World Automation Congress 2010, 2010
17. J.P. García-Sandoval, B. Castillo-Toledo, S. Di Gennaro, V. González-Álvarez, Structurally Stable Output Regulation Problem With Sampled-Output Measurements Using Fuzzy Immersions, IEEE Transactions on Fuzzy Systems, Vol. 18, No. 6, pp. 1170-1177, 2010
18. A. Girard, G. Pola, P. Tabuada, Approximately bisimilar symbolic models for incrementally stable switched systems, IEEE Transaction on Automatic Control, 55(1):116-126, 2010
19. D. Gómez-Gutiérrez, A. Ramírez-Treviño, Javier Ruiz-León, S. Di Gennaro, Observability of Switched Linear Systems: A Geometric Approach, Proceedings of the 49th IEEE Conference on Decision and Control, Atlanta, USA, 2010
20. F. Graziosi, C. Rinaldi, F. Tarquini, RF Sounding: A System for Generating

Sounds from Spectral Analysis, Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering
21. H. Ito, P. Pepe, Z.-P. Jiang, A small-gain Condition for iISS of interconnected retarded systems based on Lyapunov-Krasovskii functionals, Automatica, 46 (10), pp. 1646-1656, 2010
22. P. Park, P. Di Marco, C. Fischione, K.H. Johansson, Adaptive IEEE 802.15.4 Protocol for Reliable and Timely Communications. Proceedings of the 9th ACM/IEEE International Conference on Information Processing in Sensor Networks, IPSN '10 , pp. 327-338
23. P. Pepe, H. Ito, On Saturation, Discontinuities and Time-Delays in iISS and ISS Feedback Control Redesign, American Control Conference, Baltimore, June 30th – July 2nd, pp. 190-195, 2010
24. A. Petriccone, G. Pola, M.D. Di Benedetto, E. De Santis, A Complexity Reduction Approach to the Detection of Safety Critical Situations in Air Traffic Management Systems, Proc. of 49th IEEE Conference on Decision and Control, Atlanta, USA, December, 2010, pp. 2081-2085
25. G. Pola, P. Pepe, M.D. Di Benedetto, P. Tabuada, Symbolic models for nonlinear time-delay systems using approximate bisimulation, Systems & Control Letters 59 (2010) 365-373
26. G. Pola, P. Pepe, M.D. Di Benedetto, Alternating Approximately Bisimilar Symbolic Models for Nonlinear Control Systems with Unknown Time–Varying Delays, Proc. of 49th IEEE Conference on Decision and Control, Atlanta, USA, December, 2010, pp. 7649-7654
27. L. Pomante, System-Level Design Space Exploration for HMPSoC. 3rd Workshop on Mapping of Applications to MPSoCs by The ArtistDesign European Network of Excellence. St. Goare (Germania), June, 2010
28. L. Pomante, P. Di Felice, M. Ianni, Design and evaluation of a spatial extension of TinyDB for wireless sensor networks, International Journal of Computers and Their Applications Manuscript, September, 2010
29. L. Pomante, F. Santucci, M. Pugliese, Optimal Wireless Sensor Networks Topologies for the support of Mobile Agent-based Monitoring and Alerting Applications. Congresso AICA. L'Aquila, September /October, 2010
30. L. Pomante, A. Spinosi, L. Lavagno, S. Olivieri, M. Mozumdar, An extended framework for the development of WSN applications. Workshop on Mobile Computing and Networking Technologies. Mosca, October, 2010
31. M. Pugliese, A. Giani, L. Pomante, F. Santucci, A Comprehensive Cross-Layer Framework for Secure Monitoring Applications based on Wireless

Sensor Networks, Congresso Nazionale AICA (Associazione Italiana per l'Informatica e il Calcolo Automatico), L'Aquila, October, 2010
32. M. Pugliese, L. Pomante, F. Santucci, Topology Optimization and Network Deployment Algorithm in WSNs for Mobile Agent-based Applications, 4th European Modelling Symposium (EMS2010), Pisa, November, 2010
33. C. Rinaldi, RF Sounding: tra Arte e Tecnologia, Atti del Convegno Biennale di Musica Elettronica La Terra Fertile 2010, Sassari, June 4-6, 2010
34. C. Rinaldi, RF Sounding: An Interactive Installation Generating Sounds from Spectral Analysis, 6es Journées Jeunes Chercheurs en Audition, Acoustique musicale et Signal audio, November 17-19, 2010, Ircam, Paris
35. C. Rinaldi, L. Pomante, F. Graziosi, R. Alesii, F. Tarquini, RF Sounding, Congresso Nazionale AICA (Associazione Italiana per l'Informatica e il Calcolo Automatico), L'Aquila, October, 2010
36. C. Rinaldi, L. Pomante, R. Alesii, F. Graziosi, Demo Abstract/RF Sounding, Proceedings of the 8th ACM Conference on Embedded Networked Sensor Systems Zurich, Switzerland, November 3-5, 2010
37. C. Rinaldi, L. Pomante, F. Graziosi, M. Lupone, RF Sounding: Listening the Cellphone, 7th International Symposium on Computer Music Modeling and Retrival, June 21-24, 2010, Malaga, Spain
38. Special Issue on Industrial Control over Wireless Networks, International Journal Robust and Nonlinear Control, M.D. Di Benedetto, F. Santucci, K.H. Johansson, M. Johansson, Guest Editors, International Journal of Robust and Nonlinear Control, Volume 20, Issue 2, page 119-122, January, 2010
39. U. Tiberi, C. Fischione, K.H. Johansson, M.D. Di Benedetto, Adaptive Self-Triggered Control over IEEE 802.15.4 Networks, Proc. of 49th IEEE Conference on Decision and Control, Atlanta, USA, December, 2010
40. E. Witrant, P. Di Marco, P. Park, C. Briat, Limitations and performances of robust control over WSN: UFAD control in intelligent buildings. IMA Journal of Mathematical Control and Information
41. E. Witrant, A. D'Innocenzo, G. Sandou, F. Santucci, M.D. Di Benedetto, A.J. Isaksson, K.H. Johansson, S.-I. Niculescu, S. Olaru, E. Serra, S. Tennina, U. Tiberi, Wireless Ventilation Control for Large-Scale Systems: the Mining Industrial Case, International Journal of Robust and Nonlinear Control 2009, Volume 20, Issue 2, Special Issue on Industrial Control over Wireless Networks, January, 2010, Pages 226-251
42. M. Zamani, G. Pola, P. Tabuada, Symbolic models for unstable nonlinear control systems, Proc. of American Control Conference 2010, Baltimore, Maryland, USA, pp. 1021-1026

2009

43. A. Abate, A. D'Innocenzo, M.D. Di Benedetto, S. Sastry, Understanding Deadlock and Livelock Behaviors in Hybrid Control Systems. Nonlinear Analysis: Hybrid Systems, Volume 3, Issue 2, May, 2009, Pages 150-162
44. R. Alur, A. D'Innocenzo, K.H. Johansson, G.J. Pappas, G. Weiss, Modeling and Analysis of Multi-Hop Control Networks. 15th IEEE Real-Time and Embedded Technology and Applications Symposium. April 13 - 16, 2009. San Francisco, CA, United States
45. R. Bajcsy, A. Borri, A. Giani, M.D. Di Benedetto, C. Tomlin, Classification of Physical Interactions between Two Subjects. Proceedings of the 6th International Workshop on Body Sensor Networks, Berkeley (U.S.A.)
46. F. Balarin, M. D'Angelo, A. Davare, D. Densmore, T. Meyerowitz, R. Passerone, A. Pinto, A. Sangiovanni-Vincentelli, A. Simalatsar, Y. Watanabe, G. Yang, Q. Zhu, Platform-Based Design and Frameworks: Metropolis and Metro II, Model-Based Design of Heterogeneous Embedded Systems; Gabriela Nicolescu, Pieter Mosterman (Eds.), CRC Press, 2009
47. D. Bianchi, A. Borri, G. Burgio, M.D. Di Benedetto, S. Di Gennaro, Adaptive Integrated Vehicle Control using Active Front Steering and Rear Torque Vectoring. Proceedings of the 48th IEEE Conference on Decision and Control, pp. 3557-3562, 2009
48. A. Borri, M.D. Di Benedetto, M.G. Di Benedetto, Hybrid Modelling, Power Management and Stabilization of Cognitive Radio Networks. In Hybrid Systems: Computation and Control 2009, P. Tabuada and R. Majumdar Eds, LNCS 5469, pp. 76-89, Springer-Verlag, Berlin Heidelberg, 2009
49. P. Caravani, E. De Santis, Observer-based stabilization of linear switching systems, International Journal of Robust and Nonlinear Control, Volume 19, Issue 14, Special Issue: Observability and observer-based control of hybrid systems, September, 2009, Pages 1541–1563
50. P. Caravani, E. De Santis, On observer based stabilization of networked systems. CDC 2009: Proceedings of the 48th IEEE Conference on Decision and Control, pp. 2017-2022, 2009
51. B. Castillo-Toledo, S. Di Gennaro, J. Anzurez-Marin, On the Fault Diagnosis Problem for Non-linear Systems: A Fuzzy Sliding-Mode Observer Approach, Journal of Intelligent and Fuzzy Systems, Vol. 20, No. 4-5, pp. 187-199, 2009
52. S. Coleri Ergen, P. Di Marco, C. Fischione, MAC protocol engine for sensor networks. IEEE Global Communications Conference – GLOBECOM, Dec

4-10 2009. Honolulu, Hawaii

53. M. D’Angelo, C. Fischione, How to Select the OOK Modulation Detection Threshold in Wireless Ad Hoc and Sensor Networks, Proc. of IEEE 67th Vehicular Technology Conference - Spring 2009 (IEEE VTC Spring 09), Barcelona, Spain, April, 2009
54. E. De Santis, M.D. Di Benedetto, A. Petriccone, G. Pola, A Compositional Hybrid System Approach to the Analysis of Air Traffic Management Systems, Proc. of the 8th Innovative Research Workshop & Exhibition, EUROCONTROL, Paris, France, 2009
55. E. De Santis, M.D. Di Benedetto, G. Pola, A structural approach to detectability for a class of hybrid systems, Automatica, 45(5):1202-1206, 2009
56. E. De Santis, M.D. Di Benedetto, G. Pola, Observability of linear switched systems, Handbook of Hybrid Systems Control, Theory, Tools, Application, J. Lunze and F. Lamnabhi-Lararrigue, Eds., Cambridge University Press, 2009, pp. 106-112
57. M.D. Di Benedetto, S. Di Gennaro, A. D'Innocenzo, Discrete state observability of hybrid systems , International Journal of Robust and Nonlinear Control, Volume 19, Issue 14, Special Issue: Observability and observer-based control of hybrid systems, September, 2009
58. M.P. Di Ciccio, P. Pepe, P.U. Foscolo, ISS Feedback Redesign for Disturbance Attenuation in Continuous Stirred Tank Reactors, 48th IEEE Conference on Decision and Control and 28th Chinese Control Conference, pp. 5965-5970, Shanghai, China, 2009
59. P. Di Marco, P. Park, C. Fischione, K.H. Johansson, A Dynamic energy-efficient protocol for reliable and timely communications for wireless sensor networks in control and automation. 5th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Networks (Posters and Demo Session) – SECON 2009, Rome, Italy
60. A. D'Innocenzo, G. Weiss, R. Alur, A.J. Isaksson, K.H. Johansson, G.J. Pappas, Scalable scheduling algorithms for wireless networked control systems. 5th Annual IEEE Conference on Automation Science and Engineering (CASE09). August 22-25, 2009, Bangalore, India
61. M. Di Renzo, F. Graziosi, F. Santucci, Approximating the Linear Combination of Log-Normal RVs via Pearson Type IV Distribution for UWB Performance Analysis, IEEE Transactions on Communications, Vol. 57, No. 2, pp. 388-403, February, 2009
62. M. Di Renzo, F. Graziosi, F. Santucci, Ei-Transform: A Useful and General Framework for Channel Capacity Analysis over Fading Channels, IEEE

Sarnoff Symposium, March 30 – April 1, 2009, Nassau Inn in Princeton, NJ, USA

63. M. Di Renzo, F. Graziosi, F. Santucci, Cooperative Spectrum Sensing in Cognitive Radio Networks over Correlated Log-Normal Shadowing, IEEE Vehicular Technology Conference–Spring, April 26–29, 2009, Barcelona, Spain
64. M. Di Renzo, F. Graziosi, F. Santucci, On the Performance of Cooperative Systems with Blind Relays over Nakagami-m and Weibull Fading, IEEE Wireless Communications and Networking Conference, April 5–8, 2009, Budapest, Hungary
65. M. Di Renzo, F. Graziosi, F. Santucci, Further Results on the Approximation of Log-Normal Power Sum via Pearson Type IV Distribution: A General Formula for Log-Moments Computation, IEEE Transactions on Communications, Vol. 57, No. 4, pp. 893-898, April, 2009
66. M. Di Renzo, F. Graziosi, F. Santucci, On the Cumulative Distribution Function of Quadratic-Form Receivers Over Generalized Fading Channels with Tone Interference, IEEE Transactions on Communications, Vol. 57, No. 7, pp. 2122-2137, July, 2009
67. M. Di Renzo, F. Graziosi, F. Santucci, A Unified Framework for Performance Analysis of CSI-Assisted Cooperative Communications Over Fading Channels, IEEE Transactions on Communications, Vol. 57, No. 9, pp. 2552-2557, September, 2009
68. M. Di Renzo, F. Graziosi, F. Santucci, A Comprehensive Framework for Performance Analysis of Dual-Hop Cooperative Wireless Systems with Fixed-Gain Relays over Generalized Fading Channels, IEEE Transactions on Wireless Communications, Vol. 8, No. 10, pp. 5060-5074, October
69. M. Di Renzo, L. Imbriglio, F. Graziosi, F. Santucci, Distributed Data Fusion over Correlated Log-Normal Sensing and Reporting Channels: Application to Cognitive Radio Networks, IEEE Transactions on Wireless Communications, 2009, 8 (12), art. no. 5351699, pp. 5813-5821
70. M. Di Renzo, L. Imbriglio, F. Graziosi, F. Santucci, C. Verikoukis, Cooperative Spectrum Sensing for Cognitive Radios: Performance Analysis for Realistic System Setups and Channel Conditions, ICST - International Conference on Mobile Lightweight Wireless Systems, May 18-20, 2009, Athens, Greece, (invited paper)
71. M. Di Renzo, L. Imbriglio, F. Graziosi, F. Santucci, Cooperative Spectrum Sensing for Cognitive Radio Networks with Amplify and Forward Relaying over Correlated Log-Normal Shadowing, ACM International Symposium

on Mobile Ad Hoc Networking and Computing, May 18-21, 2009, New Orleans, LA, USA
72. M. Di Renzo, L. Imbriglio, F. Graziosi, F. Santucci, Smolyak's Algorithm: A Simple and Accurate Framework for the Analysis of Correlated Log-Normal Power-Sums, IEEE Communications Letters, Vol. 13, No. 9, pp. 673-675, September, 2009
73. M. Di Renzo, L. Imbriglio, F. Graziosi, F. Santucci, Second-Order Statistics of Amplify-and-Forward Multi-Hop Wireless Networks: A Framework for Computing the End-to-End SNR Auto-Correlation Function over Log-Normal Shadowing Channels, IEEE International Conference on Ultra Modern Telecommunications (ICUMT) - International Workshop on Wireless and Optical Networks, October 12-14, 2009, St. Petersburg, Russia
74. M. Di Renzo, L. Imbriglio, F. Graziosi, F. Santucci, Cooperative Spectrum Sensing over Correlated Log-Normal Sensing and Reporting Channels, IEEE Global Communications Conference, November 30 - December 4, 2009, Honolulu, Hawaii, USA
75. M. Di Renzo, D. De Leornardis, F. Graziosi, F. Santucci, On the Robustness of Tc-DTR UWB Receivers to Narrow-Band Interference: Performance Analysis and Guidelines for System Optimization, IEEE International Conference on Ultra-Wideband, September 9-11, 2009, Vancouver, Canada
76. M. Di Renzo, D. De Leornardis, F. Graziosi, F. Santucci, Detection and False Alarm Probability of IR-UWB Chip-Time Differential Transmitted Reference Receivers: A Framework for Performance Analysis and Optimization over Multipath Fading Channels with Tone Interference, IEEE Military Communications Conference, October 19-21, 2009, Boston, USA
77. M. Di Renzo, F. Tempesta, L.A. Annoni, F. Santucci, F. Graziosi, R. Minutolo, M. Montanari, Performance Evaluation of IR-UWB D-Rake Receivers over IEEE 802.15.4a Multipath Fading Channels with Narrow-Band Interference, IEEE International Conference on Ultra-Wideband, September 9-11, 2009, Vancouver, Canada
78. C. Fischione, S. Tennina, F. Santucci, F. Graziosi, Reliability and Efficiency Analysis of Distributed Source Coding in Wireless Sensor Networks, IEEE ICC 2009 Ad Hoc and Sensor Networking Symposium, Dresden, Germany
79. C. Fischione, M. Butussi, K.H. Johansson, M. D'Angelo, Power and Rate Control with Outage Constraints in CDMA Wireless Networks, IEEE Transactions on Communications, 2009

80. A.A. Julius, A. D'Innocenzo, G.J. Pappas, M.D. Di Benedetto, Approximate equivalence and synchronization of metric transition systems. Systems & Control Letters, Volume 58, Issue 2, February, 2009, Pages 94-101
81. P. Park, P. Di Marco, P. Soldati, C. Fischione, K.H. Johansson, A generalized Markov chain model for effective analysis of slotted IEEE 802.15.4. 6th IEEE International Conference on Mobile Ad Hoc and Sensor Systems – MASS 2009. Macao SAR, P.R.C.
82. G. Pola, P. Pepe, M.D. Di Benedetto, P. Tabuada, A symbolic model approach to the digital control of nonlinear time–delay systems, 48th IEEE Conference on Decision and Control and 28th Chinese Control Conference, Shanghai, China, December, 2009, 2216-2221
83. G. Pola, P. Tabuada, Symbolic models for nonlinear control systems: Alternating approximate bisimulations, SIAM Journal on Control and Optimization, 48(2):719-733, 2009
84. L. Pomante, P. Di Felice, Ad-hoc Architectures for modern DBMS: a HW/SW Co-Design Approach. DATE'09 Workshop on Designing for Embedded Parallel Computing Platforms: Architectures, Design Tools, and Applications, Nizza, April, 2009
85. L. Pomante, F. Graziosi, L. Imbriglio, Application-Specific System-Level Design Space Exploration for Heterogeneous Multiprocessor Embedded Platforms. DATE'09 Workshop on Designing for Embedded Parallel Computing Platforms: Architectures, Design Tools, and Applications, Nizza, April, 2009
86. L. Pomante, F. Graziosi, L. Imbriglio, System-Level Design Space Exploration for Application-Specific HW/SW Systems. 2009 IEEE Toronto International Conference-Science and Technology for Humanity (TIC-STH 2009): Symposium on Electronic Design Automation, Toronto, September, 2009
87. L. Pomante, S. Tennina, F. Graziosi, M. Di Renzo, R. Alesii, F. Santucci, Localization, tracking, and automatic personal identification in GPS-denied environments: a solution based on a wireless biometric badge, 5th ICST/IEEE/ACM TridentCom, Washington DC (USA), April, 2009
88. L. Pomante, S. Tennina, F. Graziosi, M. Di Renzo, R. Alesii, F. Santucci, Integrated GPS-denied Localization, Tracking and Automatic Personal Identification. 20th Tyrrhenian International Workshop on Digital Communications, Springer Book Series 2009
89. M. Pratesi, A. Colarieti, F. Santucci, A. Di Cola, S. Schillaci, A testbed for emulation of MANETs in hostile scenarios; Wireless Communication Systems, 2009. ISWCS 2009. September 7-10, 2009

90. M. Pugliese, A. Giani, F. Santucci, Weak Process Models for Attack Detection in a Clustered Sensor Network using Mobile Agents, in 1st International Conference on Sensor Systems and Software (S-CUBE2009), Pisa, September, 2009
91. M. Pugliese, L. Pomante, F. Santucci, Agent-based Scalable Design of a Cross-Layer Security Framework for Wireless Sensor Networks Monitoring Applications, in International Workshop on Scalable Ad Hoc and Sensor Networks (SASN2009), Saint Petersburg, October, 2009
92. Special Issue on Observability and observer-based control of hybrid systems, E. De Santis, M.D. Di Benedetto, Guest Editors, International Journal of Robust and Nonlinear Control, Volume 19, Issue 14, pages 1519–1520, September 25, 2009
93. S. Tennina, M. Di Renzo, F. Graziosi, F. Santucci, Distributed Localization Algorithms for Wireless Sensor Networks: From Design Methodology to Experimental Validation, Book chapter in Wireless Sensor Network, ISBN 978-3-902613-49-3
94. S. Tennina, M. Di Renzo, F. Graziosi, F. Santucci, ESD: A Novel Optimization Algorithm for Positioning Estimation of WSNs in GPS-denied Environments - From Simulation to Experimentation, International Journal of Sensor Networks, Vol. 6, No. 3/4, pp. 131-156
95. S. Tennina, L. Pomante, F. Graziosi, M. Di Renzo, R. Alesii, F. Santucci, Distributed Localization, Tracking, and Automatic Personal Identification: A Solution based on a Wireless Biometric Badge, ACM International Workshop on Wireless Network Testbeds, Experimental Evaluation and Characterization (conjunction with the ACM Annual International Conference on Mobile Computing and Networking), September 20-25, 2009, Beijing, China, (demo-paper)
96. S. Tennina, L. Pomante, F. Graziosi, M. Di Renzo, R. Alesii, F. Santucci, Integrated GPS-denied Localization, Tracking and Automatic Personal Identification, Research Demo Session at SenSys'09, November 4–6, 2009, Berkeley, CA, USA. ACM 978-1-60558-748-6
97. G. Weiss, A. D'Innocenzo, R. Alur, K.H. Johansson, G.J. Pappas, Robust Stability of Multi-Hop Control Networks. In Proceedings of the 48th IEEE Conference on Decision and Control. December 16-18, 2009. Shangai, China
98. Special Issue on Observability and observer-based control of hybrid systems, E. De Santis, M.D. Di Benedetto, Guest Editors, International Journal of Robust and Nonlinear Control, Volume 19, Issue 14, pages 1519–1520, September 25, 2009