IST-214373 ArtistDesign
Network of Excellence
on Design for Embedded Systems

Activity Progress Report for Year 2

Real-Time Networks

Clusters:

Operating Systems and Networks

Activity Leader:

Luis Almeida (University of Porto, Portugal)

http://www.fe.up.pt/

Policy Objective (abstract)
This activity addresses the problems posed by the growing role of networking within the frameworks of Networked Embedded Systems (NESs), Wireless Sensor Networks (WSNs) and Mobile Adhoc Networks (MANETs). Its main objectives are the timing analysis of communication protocols, the development of new protocols that are analysable while being dynamically reconfigurable and adaptable, the support for higher integration levels within distributed embedded systems, the reduction of communication related energy-consumption and the support for a progressive replacement of wired with wireless networking technologies.

Versions

number	comment	date
1.0	First version delivered to the reviewers	December 18th 2009

Table of Contents

1. Overview of the Activity

1.1 ArtistDesign participants and their role within the Activity

Cluster Leader: Giorgio Buttazzo – Scuola Superiore S. Anna (Italy)
Role: Activity coordinator, kernel maintenance, development of robotic applications.

Team Leader: Luis Almeida – University of Porto (Portugal)
Role: networking platform, development of distributed applications.

Team Leader: Gerhard Fohler – Technical University of Kaiserslauten (Germany)
Role: video streaming applications, scheduling.

Team Leader: Michael Gonzalez Harbour – University of Cantabria (Spain)
Role: definition of the POSIX operating system interface.

Team Leader: Alan Burns – University of York (UK)
Role: feasibility analysis of fixed priority real-time systems.

Team Leader: Eduardo Tovar – Polytechnic Institute of Porto (Portugal)
Role: distributed applications and QoS over heterogeneous networks.

-- Changes wrt Y1 deliverable --
The University of Aveiro (Portugal) was replaced by the University of Porto (Portugal) following the move of the team leader from the former institution to the latter.

1.2 Affiliated participants and their role within the Activity

Team Leader: Paulo Pedreiras – University of Aveiro (Portugal)
Role: real-time networks, dynamic quality of service management.

Team Leader: Hermann Haertig – Universtity of Dresden (Germany)
Role: microkernel architectures and virtualization techniques

Team Leader: Pau Marti – Universitat Politècnica de Catalunya (Spain)
Role: control applications and schedulability of event-driven control systems.

Team Leader: Marisol García Valls – Carlos III University of Madrid (Spain)
Role: memory management in real-time Java middleware.

Team Leader: Jean-Dominique Decotignie – CSEM (Switzerland)
Role: networks.

Team Leader: Lucia Lo Bello – University of Catania (Italy)
Role: QoS-oriented scheduling and management of communication and processing.

Team Leader: Julian Proenza – University of the Balearic Islands (Spain)
Role: fault-tolerance.

Team Leader: Dirk Pesch – Cork Institute of Technology (Ireland)
Role: adaptive wireless systems, wireless sensor networks

Team Leader: Liesbeth Steffens - NXP Semiconductors (the Netherlands)
Role: industrial partner, video streaming, in-car networks, sensor networks

Team Leader: Tullio Facchinetti – University of Pavia (Italy)
Role: embedded real-time systems and robotics applications.

-- Changes wrt Y1 deliverable -- *University of Aveiro (Portugal), is now an affiliated partner.*

1.3 Starting Date, and Expected Ending Date

Starting date: January 1st, 2008

Ending date. December 31st, 2010.

Despite the precise dates specified above, it is likely that this activity will continue beyond the end of ArtistDesign, given the growing role of networking within embedded system for the foreseeable future and the needed research for new protocols and technologies that will allow integrating subsystems in a composable way, support cooperation among larger numbers of nodes, cope with variations in topology and resources availability, and provide truly physically dispersed interaction with the environment.

-- Changes wrt Y1 deliverable --

No changes with respect to Year 1.

1.4 Policy Objective

This activity addresses open research issues within the general framework of networked embedded systems, including not only the wired distributed embedded systems typically found in confined environments but also their extension to large-scale set-ups with wired/wireless mixed topologies including wireless sensor networks, and also the case of mobile ad-hoc networks with nodes that join and leave the network dynamically. Beyond such main framework, some attention will also be dedicated to networks-on-chip, particularly within multi-core systems-on-chip, and cyber-physical systems, given the growing importance of these topics.

Specifically, this activity aims at:

- analysing what kind of timeliness guarantees can be achieved across those frameworks and which mechanisms can be devised to grant such guarantees, particularly under the dynamic behaviour arising from load variations, topology changes, adaptation to the environment or other reconfigurations;
- fostering the currently increasing integration levels within distributed embedded systems, by means of efficient temporal partitioning and isolation, integrated global resource management and flexible architectures;
- pursuing further energy-consumption reduction in networking, particularly in wireless sensor networks and mobile devices in general, both from device and system perspectives;
- addressing the problems brought up by and devise solutions to the current trend towards the systematic and progressive replacement and/or extension of wired with wireless networking technologies, from embedded control applications to multimedia systems.
- influencing industry through courses and seminars to raise awareness to emerging techniques/technologies, through participation in emerging standardisation efforts such WirelessHART (within ISA100 and IEC TC65 WG16), ZigBee/IEEE802.15.4, and through joint R&D projects.

-- Changes wrt Y1 deliverable --

No changes with respect to Year 1.

1.5 Background

Along the past decades, several network communication protocols have been developed with new capabilities, from an ever increasing throughput and support for traffic classes (including guaranteed latency and jitter), to different topologies, integration of heterogeneous segments, extensive use of wireless technologies, openness to dynamic arrival and departures of nodes, openness to larger networks (such as the Internet), etc. If, on one hand, many problems have been solved, with a significant number of successful embedded applications that rely on networking services, on the other hand new problems appeared, or some old problems persist, that still require adequate solutions. The following non-exhaustive list highlights some open research issues that will establish the baseline for this activity.

Energy-efficient communication
Energy-efficient communication, particularly in WSN, is still an open issue requiring innovative networking protocols that manage communications periodicity, nodes synchronisation, transmission power and routing. Several research protocols exist but ZigBee and its data link layer IEEE802.15.4, as well as other technologies such as Bluetooth low power, need particular attention given their growing popularity in the wireless sensor networks arena.

Networks of nodes with scarce resources
Nevertheless, energy is not the only concern. In fact, there is currently a trend in distributed sensing, actuation and co-operative computing, be it for surveillance, environment and critical infrastructures monitoring, disaster recovery operations, distributed control or military operations, towards using small and tiny platforms. Moreover, a new area is emerging, the so-called Body Area Networks (BANs – IEEE802.15.6) that integrate tiny communicating nodes embedded in personal objects, clothes, shoes and even medical implants. The scarce resources of these platforms and the requirements imposed by such diverse applications necessarily imply different trade-offs on supported functionality, quality of service, efficiency, platforms, protocols, architectures, etc.

Scalability issues in large sensor systems
Sensor networks with 1000 sensor nodes are already being planned today but tens of thousands of nodes are foreseeable within a few years. Planning, installing, commissioning and operating such networks is a challenging task given their dimension. But these are not the only challenges. For example, aggregating the enormous amounts of data into a small set of meaningful quantities in a scalable and efficient way, discovering services available or areas covered, routing the data efficiently and in time, developing interaction models that are adequate to support applications built on top of such infrastructures, are all challenges that need to be revisited having scalability in mind.

Networking support to middleware
Another challenge that remains open is the efficient integration of network protocols into higher level middleware, e.g., to efficiently support properties like transparent distribution, true multicasting, publisher-subscriber interaction models, integrated distributed resource management or service composition and interaction for service-oriented computing. One specific middleware that will be considered is the contract-based framework that is being developed within the FRESCOR project, aiming at providing a uniform approach for the application to express its QoS and timing requirements with respect to any system resource. The challenge will be to provide the required network services at the lowest possible levels of the architecture, to efficiently support the pursued virtual resource abstraction. Similarly, special attention will be devoted to the support of the service-oriented paradigm and its use to facilitate development of distributed embedded systems.

Quality-of-Service adaptation and graceful degradation
QoS adaptation and the collaborative computing paradigms are challenges that will require protocol mechanisms that monitor instantaneous bandwidth usage, enforce minimum agreed QoS levels (e.g. through contracts and traffic policing) and leverage the access to free bandwidth (to increase QoS whenever possible). This issue is also addressed by the FRESCOR project and also by other approaches such as the Flexible Time-Triggered (FTT) framework, which carry out such adaptation at the data link level, where it can be more resource efficient than solutions based on the Internet Protocol, such as RSVP. On the other hand, these adaptation techniques can also be applied to provide graceful degradation in distributed systems, thus supporting cost effective fault-tolerance mechanisms that rely on replicas providing different levels of service using spare resources (unintended redundancy).

Higher software integration
Another challenge is to support higher software integration in distributed embedded systems requiring integrated global resource management together with effective and efficient temporal partitioning as well as flexible mapping between software and hardware architectures. Hierarchical scheduling and component-based techniques seem particularly adequate to this purpose but they need proper support from the networking infrastructure. Some attention will be devoted to related frameworks like AUTOSAR in the automotive industry, IEC61499 in industrial automation and ARINC 653 in the avionics domain.

Wireless communication everywhere
Another issue that remains open is the replacement and/or extension of wired with wireless networking technologies in domains requiring timing guarantees, e.g., industrial automation, coping with more error-prone channels but profiting from simplified deployment and elimination of cabling (see the on-going ISA 100 standardisation efforts). Note that the use of wireless technologies, as openness in general, poses many challenges related to security, such as intrusion avoidance and tolerance as well as enforcement of data privacy. Despite their high importance, these challenges will not be addressed in this activity but awareness to them will allow following the relevant research results developed elsewhere.

-- Changes wrt Y1 deliverable --

No changes with respect to Year 1.

1.6 Technical Description: Joint Research

The work-programme for this activity includes the development of specific protocols and associated analysis tools to provide some level of timeliness guarantees and minimize energy consumption in WSNs and MANETs, protocols to enforce agreed QoS levels in NESs (wired/wireless) and also to support dynamic QoS management, dynamic reconfiguration and other run-time adaptation methods to achieve efficient resource usage and less expensive fault tolerance.

It is also foreseen that joint research will be developed on: (i) the design distributed algorithms for computing basic operations in large-scale networked embedded sensor systems such that their time-complexity is independent of the number of sensor nodes and; (ii) showing their usefulness in the application areas of control of physical systems and sensor fusion (taking into account the dynamic nature of such communication infrastructures); and (iii) the support of

Quality-of-Service (QoS) in wireless sensor networks with the additional goal to contribute to the standardization process on IEEE 802.15.4/ZigBee suite of protocols.

The first 18 months targeted research along the above referred lines, carried out collaboratively by several groups. A special target was set on producing two taxonomies, one of WSNs for time-sensitive applications, addressing the existing protocols, their features and limitations, as well as the respective middleware for application development, and the other of flexibility in NES, addressing several perspectives of the concept, from design flexibility to configuration flexibility, operational flexibility etc, but also within the scope of real-time distributed applications with more or less criticality. However, it was found that the latter taxonomy overlapped with a similar effort being done within the transversal activity on Design for Adaptivity and thus both efforts were merged. The work on the taxonomies is still in-progress and will enter into the third year.

-- Changes wrt Y1 deliverable --

Minor updates with respect to Year 1 to reflect the continuation of the work on the taxonomies.

1.7 Work achieved in Year 1

During the first year, the teams involved in this activity explored several of the specific lines referred in section 1.5 that are related to the two main topics covered in the activity, i.e., WSNs and flexibility in NES. The actual lines addressed are briefly described below.

a) Issues in WSNs using standard protocols and COTS technologies

This problem has been addressed mainly within the ART-WiSe framework (http://www.hurray.isep.ipp.pt/ART-WiSe), involving researchers from **Porto, Catania, Pisa, York** and **Prague**. Main focus is on how to use IEEE 802.15.4 and ZigBee as federating communication protocols for WSN applications with QoS requirements (e.g. real-time, reliability, energy-efficiency, scalability, topology management). Research includes the provision of timeliness guarantees, evaluation models, simulation tools, energy-efficiency, cluster tree topologies, network dimensioning and admission control. The objective is to use not only standard communication protocols (IEEE 802.15.4/ZigBee), but also COTS technologies such as operating systems (e.g. TinyOS and ERIKA) and hardware platforms (e.g. MICAz, TelosB, Stargate SBC).

b) Scalable data aggregation in WSNs

WiDom (Wireless Dominance protocol) and WiSe-CAN (Wireless Sensor Networks protocol based on the Controller Area Network protocol) are two related research efforts that have evolved through this year involving researchers from **Porto** and **Vienna**. We target at dealing with sensor faults and using the approach to perform localisation.

c) Mobility in real-time wireless networks

Mobility in wireless networks adds to the complexity of achieving real-time communication given the dynamic topology and dynamic communication links. This problem was addressed by **Aveiro**, concerning the self co-ordination of teams of mobile units with variable number of team members and resilience to uncontrolled traffic, external to the team. The technology considered was plain DCF IEEE 802.11.

d) Robust communication with star topologies

In wired networks, star topologies are typically associated to a higher level of robustness because, in one hand, they reduce the multiple points-of-failure typically present in a bus to

one single point-of-failure, i.e., the star hub, and in the other hand the star hub is also a natural point for error containment, be it in the value or time domains. However, typical wired networked embedded systems use either bus topologies or star topologies that have limited confinement capabilities. For example, CAN buses, which are commonly found in embedded systems due to their low cost and simplification of cabling, exhibit low error confinement capabilities and thus a simple fault in the medium or in a transceiver may render the network useless.

On the other hand, current COTS Ethernet switches also have relatively poor traffic scheduling capabilities (FIFO queues and very few priority levels) and poor protection against misbehaving nodes, namely in the time domain. Therefore, it is possible that a node suffering from a time domain fault, such as a babbling idiot, can cause a substantial negative impact system wide. Improving this aspect by including more protection capabilities in the switches, mainly in the time domain, was considered an important aspect. Both the stars for CAN and Ethernet were addressed by **Aveiro** and **Mallorca** with support from **CMU** in the case of Ethernet.

e) Real-time network support to middleware layers.

The development of complex distributed applications requires appropriate support from a middleware layer that provides an adequate abstraction level. There are nowadays several types of middleware that abstract away certain properties of the underlying platforms and facilitate application development. Service-oriented middleware is one such case that improves functional flexibility at run-time. However, existing service-oriented middlewares do not support real-time guarantees. Improving this situation and bringing Service-oriented Architectures to the real-time applications domain has been tackled by **Madrid** (UC3M) and **Aveiro**. These groups have also tackled the problem of supporting synchronisation of distributed communications based on the Java language, allowing to control the relative phase of remote methods invocations and thus the level of contention at the servers access, resulting in improved timeliness and lower queuing requirements for server requests.

Cantabria, Valencia and **Prague**, on the other hand, focused on the FRESCOR contracting middleware and have added support to it in several communication networks: CAN bus, as a representative of fieldbuses, WiFi, as a representative of wireless networks, wired Ethernet, and switched Ethernet using industrial switches.

f) Providing network support for safe integration

When increasing the integration levels in distributed applications, the risk for mutual interference among different streams and tasks increases. One way to mitigate such risk at the network level consists in using protocols that support composability. This has been tackled by **Aveiro** and **Mälardalen** concerning composability with respect to timeliness by means of using server-based CPU scheduling techniques in the scope of traffic scheduling.

-- No changes wrt Y1 deliverable --

This section was already presented in the Y1 deliverable, in sections 1.7 and 2.1.

1.8 Problem Tackled in Year 2

During the second year, the teams involved in this activity explored several of the specific lines referred in section 1.5 that are related to the two main topics covered in the activity, i.e., WSNs and flexibility in NES. Moreover, special attention was devoted to specific application domains for their current relevance, namely wireless communication in industrial scenarios, support to intelligent transportation and healthcare systems. The actual problems tackled in this period are briefly described below.

a) Wireless sensor networks

Timeliness in Wireless Sensor Networks – Time analysis that cope with the inherent non-deterministic data delivery in these networks, the structuring /clustering of such networks to reduce end-to-end delays, and access protocols with more efficient arbitration mechanisms, namely based on dominance properties.

Mobility issues in ad-hoc real-time wireless communication – Middleware to support real-time cooperation among autonomous agents, graceful degradation of real-time protocols with respect to interference caused by alien traffic and support to relative localization and navigation.

b) Networked embedded systems

Robust communication with star topologies - Quantitative comparison of the error-containment capabilities of bus and star topologies.

Real-time support to middleware and composability – Use of synchronous techniques within standard distribution middleware (CORBA, RMI, DDS...) to improve its timeliness.

Analysis for specific networks – Improvement of the analysis for CAN with dynamic bandwidth assignment, assessment of current DC-powerline technology for real-time communication, analysis for FlexRay and for general token-passing protocols.

c) Specific application domains

Wireless networks in industrial environments – Characterization and assessment of interferences in such environments, assessment of the effectiveness of the QoS mechanisms in IEEE802.11e within industrial environments and topological issues to cater for the needs of industrial systems.

Supporting Intelligent Transportation Systems – Integration of heterogeneous and pervasive components in a consistent real-time information system, heavily based on wireless networking.

Networked Embedded Systems for Healthcare – Integration of weareable wireless communication-enabled devices to monitor the condition of patients and the level of physical activity. Provision of the needed level of dependability in such systems.

-- The above is new material, not present in the Y1 deliverable --

2. Summary of Activity Progress in Year 2

2.1 Technical Achievements

a) Timeliness in Wireless Sensor Networks (TUKL, CSEM, Philips, Pisa, York, Porto)

The inherent properties of Wireless Sensor Networks (WSN) clash with the notion of timeliness adopted from classic real-time systems. It is practically unfeasible to impose strict deadlines on single messages in WSN without overdimensioning network capacity: mobility, irregular topology, ad-hoc infrastructure, energy constraints, and limited availability of resources, constitute an unfavorable environment for such timeliness guarantees. Therefore, the teams at **TUKL, CSEM** and **Philips** proposed a generalized notion of timeliness which suits the characteristics of WSN. It allows to express the end-to-end timeliness requirements of message streams by means of target time intervals and confidence level [TUKL1] [TUKL2].

Following a different approach, **Pisa** has provided a model based on geographic and/or geographic with opportunistic routing to discover the network behavior in term of delay and number of hops. In particular this approach aims to compute the probability that a packet sent by the source node S can arrive at the destination node D, using a single or a multi-hops path, with a determined E2E delay. This expression is function of some network parameters, like the density of nodes, so we can tune that in order to obtain the network behavior requested by the applications. **Pisa** also proposed an opportunistic implementation of geographic routing able to provide the right trade-off between the network reliability and the network overload due to multiple retransmissions of the same message. [Pisa1]

York concentrated on two directions. One has looked at tuning protocols, rather than proposing new ones, using two different techniques. The first technique is Design of Experiment [York1][York2] and the second Multi-Objective Genetic Algorithms [York3]. A comparison of the two is contained in [York3]. The objectives considered include the usual end-to-end communications time and energy but also reliability and robustness. Other work has investigated how different protocols fair in a range of situations, the trade-offs involved in choosing parameters, and in particular identifies emergent behaviours with respect to network configuration, e.g. network density [York4]. Another direction developed a cellular approach to sensornets which basically places a logical structure on a large network such that groups of nodes, e.g. 10 nodes, form a cell. Within a cell protocols have been developed for managing who communicates when to avoid interference [York5] and duty cycling to maximise battery life [York6].

Porto and **Prague** have continued the development of methodologies for modeling cluster-tree WSNs where the sink can either be static or mobile [POc1, POc2]. This methodology enables the computation of the worst-case end-to-end delays, buffering and bandwidth requirements across any source-destination path in a cluster-tree WSN. It was instantiated for the particular case of IEEE 802.15.4/ZigBee cluster-tree WSNs and validated through a comprehensive experimental study using commercially available technology, namely TelosB motes running TinyOS. A MATLAB tool for the Worst-Case Dimensioning of IEEE 802.15.4/ZigBee Cluster-Tree WSNs is available as an open-source
http://www.open-zb.net.

Porto also continued the ART-WiSe research framework around the use of IEEE 802.15.4 and ZigBee as federating communication protocols for WSN applications with QoS requirements (energy-efficiency, timeliness, throughput, reliability). In this context and in this reporting period, a Hidden-Node Avoidance Mechanism (H-NAMe) for wireless sensor networks has

been proposed and validated through extensive simulation and experimental analysis [PO1, PO2, PO3].

b) Mobility issues in ad-hoc real-time wireless communication (Aveiro, UnivPorto, Zaragoza, Zhejiang, Pavia)

Aveiro and **UnivPorto** continued the work towards supporting the co-ordination of dynamic teams of mobile units, e.g., sensing units, in open environments. This year the reconfigurable and adaptive TDMA protocol developed in the previous year and based on IEEE 802.11 was completed with a middleware layer that facilitates real-time data distribution, global sensor fusion and co-ordinated behaviours [AvUP4]. This middleware had a substantial impact in the RoboCup community being used by two of the most prominent teams. It was also the basis for the development of a set of guidelines for structuring the wireless communication in that community [AvUP3].
http://www.ieeta.pt/atri/cambada/

For real-time communication in a dynamic multi-hop topology, as typical in such robotic cenarios, the University of **Zaragoza** has proposed a specific proactive routing protocol in IEEE 802.11 that does continuous topology tracking. Such protocol, however, has a sudden performance degradation when in the presence of strong interference from alien traffic. During this period, a cooperation was started with **UnivPorto** to provide graceful degradation in such conditions. Early results confirm the desired gracefulness and are being prepared for publication.

Another fundamental issue is the relative localization among the set of mobile units. **Aveiro**, **UnivPorto** and the **University of Zhejiang** in China have been researching relative localization and navigation methods based solely on ad-hoc wireless communication, using IEEE 802.15.4, facilitating the deployment of teams of surveillance mobile robots [AvUP2] [AvUP5].

Pavia, Aveiro and **UnivPorto** continued the series of Student Design Competitions in the scope of the IEEE Real-Time Systems Symposium, this year called CyberRescue@RTSS2009 and lead by **Pavia**. This is a testbed for mobile ad-hoc networks for small teams of cooperating autonomous robots that must co-ordinate their movements to maintain radio connection while maximising the area coverage. The competition site has all the necessary tools to participate. The simulator, which can be used equally for research purposes, was turned into an open development project.
http://robot.unipv.it/cyberrescue-RTSS09/
http://sourceforge.net/projects/cpss/files/

c) Robust communication with star topologies (Aveiro, UnivPorto, Mallorca, Mälardalen)

Aveiro and **Mallorca** continued the development of the (Re)CANcentrate stars for CAN, aiming at improved error containment with respect to the common bus topology. A summary of the framework was published during this reporting period in [Av+5]. A particular result achieved in this period is, as we believe, the first quantitative comparison of the error-containment capabilities of a bus and a star topology in CAN networks, which was accepted for publication [Av+2]. Special attention was also devoted to replication management in ReCANcentrate [Av+7].
http://dmi.uib.es/~mbarranco/srvlsestars/

On the other hand, **Aveiro** and **UnivPorto** continued the development of a new Ethernet switch that carries out traffic scheduling with resource reservation, controlling the

transmissions, and verifying at the input the compliance of the incoming streams with their negotiated properties. Such a switch can implement network partitions in the links that are strictly enforced by the switch itself, in a completely transparent way with respect to the end nodes, either in terms of application software but also operating system and network device driver. This results in an integration capacity with timeliness control that goes beyond what current networks offer. Moreover, such partitions can be reconfigured and adapted online by the switch, which is another unique property among similar devices. The use of server-based CPU scheduling techniques in the switch to confine the traffic to the partitions was also done in cooperation with **Mälardalen** and a prototype is described in [Av+6]. A new architecture for this switch, following a HW-SW co-design approach, appears in [AvUP1]. The switch development is supported by the HARTES national project.
http://www.ieeta.pt/lse/hartes/

d) Real-time support to middleware and composability (Aveiro, UnivPorto, Madrid, Bilbao, Cantabria)

Aveiro and **UnivPorto** have been cooperating with other partners to improve the real-time support to distribution middlewares, namely with **Bilbao** (UPV/EHU) in the scope of RT-CORBA and **Madrid** (**UC3M**) concerning Distributed RTSJ and their prototype DREQUIEMI. These efforts are based on the FTT (Flexible Time-Triggered) paradigm. Particularly, the latter resulted in two publications, one focused on D-RTSJ and DREQUIEMI [UC+1] and the other focused on composition of services in service-based applications [UC+2]. This is also a topic of the iLAND ARTEMIS project that includes these teams and aims at developing a common middleware for real-time and dynamically reconfigurable applications.
http://www.iland-artemis.org/

Madrid (UC3M) has also continued the work on functional composition mechanisms over real-time networks focusing at the level at which compositional middleware is integrated closely with the network and their synchronization mechanisms [UC3M1] [UC3M3] and interaction with remote communication protocols [UC3M2]. Also, this work has been integrated with work on mode changes on single platforms [UC+3] to obtain better dynamic performance results in multimedia systems. **Madrid** (UC3M) is also involved in a Spanish National Project of the Ministry of Industry for building gateways for the DDS standard of the OMG.

Cantabria, has continued the work on generalizing the real-time scheduling support in network communications middleware. The main goal is to support systems using different kinds of scheduling policies, including those based on adaptive resource reservation techniques such as those developed in the FRESCOR project. The chosen platform for this work has been the PolyORB middleware, supporting both the Ada DSA middleware and CORBA. This middleware has been extended with support for the management of remote calls with real-time requirements, identification of schedulable entities, support for the transactional model and the assignment of scheduling parameters. As a result, a real-time distribution middleware capable of managing different scheduling policies under a generic interface has been obtained [Cant1] [Cant2].

Work has been initiated also to try to do the same generalization for middleware based on the DDS (Data Distribution Service) OMG standard. For this purpose, a PhD student from Cantabria has initiated a five-month stay in RTI, in Santa Clara, California. RTI is a leading company in DDS middleware.

e) Analysis for specific networks (NXP, TUKL, Pavia, Aveiro/UnivPorto, Mälardalen, Pisa, Catalonia)

NXP and **TUKL** among a set of ten organizations are involved in the ARTEMIS project INDEXYS – INDustrial EXploitation of the genesYS cross-domain architecture, triggered in this period. The work of these teams aims at in-vehicular networks with focus on FlexRay.
http://www.indexys.eu/

Pavia, **Aveiro, UnivPorto** and **Mälardalen** continued their collaboration in the scope of automotive systems concerning the use of DC powerline networking technology, particularly assessing a physical and datalink layer issues of a specific technology provided by the Yamar company. The results, partially presented in [Av+8] and [Av+9] have shown several shortcomings of the medium access control concerning the timing behavior. On-going efforts are redirected to the analysis of other technologies, e.g. from Selectron.

Pisa also addressed the analysis for token-passing networks [Pisa2] and the problems that can occur in CAN [Pisa3]. **Catalonia** has developed a novel schedulability analysis for control messages of control loops built on top of the CAN that are dynamically allocated bandwidth according to the respective controlled plants' state. The schedulability analysis is based on worst-case response time techniques for real-time CAN applications [Cat1].

f) Wireless networks in industrial environments (Catania)

Catania continued analysing the use of IEEE802.15.4 in industrial scenarios. Based on both best practices followed by the industry and previous experience on interference assessment, the team developed a generic methodology for the evaluation of cross-channel interference between IEEE 802.15.4 networks in industrial environments [CT1]. Such a methodology is generic and easy to adopt in real deployments, as it relies only on standard IEEE 802.15.4 primitives and components, and allows for on-the-fly but accurate on-site assessments. Moreover, in [CT1] a case study platform based on COTS IEEE 802.15.4 devices is described and the results obtained are discussed, in order to show how to apply the proposed methodology to a real scenario.

Catania also carried out an analysis of the current achievements regarding the IEEE 802.11e protocol in industrial communication, with a special focus on the support provided to real-time traffic in factory automation. This work resulted in a book chapter [CT2], which addresses analytic performance models of both EDCA and HCCA as well as the most relevant admission control algorithms currently in literature and some improved scheduling algorithms for HCCA. In addition, as analytic models prove that the EDCA performance strongly depends on the protocol parameters, some mechanisms that control those parameters to improve the performance of the EDCA traffic are discussed as well. Finally, this chapter discusses the results from case studies that analyze the performance of IEEE 802.11e networks in realistic industrial scenarios.

Under the flexWARE Project that aims at providing real-time communication on the factory floor with wireless local area networks, **Catania** investigated the suitability of both the IEEE 802.11 [CT3] and IEEE 802.15.4 [CT4] protocols for a two-tiered network architecture for factory communication, outlining a common network architecture and analyzing the advantages of each of these protocols together with the open issues that are currently being addressed by the project.
http://www.flexware.at/

g) Supporting Intelligent Transportation Systems (Pisa, Evidence)

Pisa and **Evidence** started a national project to set up a pervasive and heterogeneous infrastructure to control urban mobility in real-time called IPERMOB. The project proposes a multi-tier approach for developing an Information System for urban mobility based on the optimization and inter-operability of data collection systems, aggregation, management, and on-line control systems, off-line systems aiming at infrastructure planning and information systems targeted to citizen and municipality to handle and rule the vehicle mobility. It uses image processing techniques to estimate traffic-related information together with vehicular networks (IEEE 802.11a/p) interoperated with WSN (IEEE 802.15.4) and connected to a centralized database through wide band 5 GHz link (IEEE 802.11h).
http://www.ipermob.org

h) Networked Embedded Systems for Healthcare (Pisa, Evidence, Catania)

Pisa and **Evidence** are starting a national project on Wireless Sensor Networks for monitoring patients with heart deseases.

Catania addressed the design issues of a networked embedded computing platform especially devised to perform physical activity assessment in different environments, such as schools, gyms, homes. A platform has been designed that allows for both constant monitoring and objective assessment of physical activity [CT5]. Such a platform comprises one or more wearable devices and a computer wireless connection that collects the sensor data to obtain an objective assessment of the physical activity. The proposed platform can be used both in schools, for the evaluation of the students physical activity, and in amateur sport, to improve the quality of athletes management during their training.

-- The above is new material, not present in the Y1 deliverable --

2.2 Individual Publications Resulting from these Achievements

Aveiro / UnivPorto

[AvUP1] R. Santos, R. Marau, Alexandre Vieira, Paulo Pedreiras, Arnaldo Oliveira, Luis Almeida. A Synthesizable Ethernet Switch with Enhanced Real-Time Features. IECON 2009, 35th Annual Conf of the IEEE Industrial Electronics Society, Porto, Portugal, 3-5 Nov 2009.

[AvUP2] Hongbin Li, Luis Almeida, Youxian Sun. Dynamic Target Tracking with Integration of Communication and Coverage using Mobile Sensors. IECON 2009, 35th Annual Conf of the IEEE Industrial Electronics Society, Porto, Portugal, 3-5 Nov 2009.

[AvUP3] Frederico Santos, Luis Almeida, Luis S. Lopes, Jose L. Azevedo, M. Bernardo Cunha. Communicating among robots in the RoboCup Middle-Size League. RoboCup Symposium 2009, Graz, Austria. June 29-July 5, 2009.

[AvUP4] Frederico Santos, Luis Almeida, Paulo Pedreiras, Luis Seabra Lopes. A real-time distributed software infrastructure for cooperating mobile autonomous robots. ICAR 2009 – 14th Int. Conf. on Advanced Robotics. Munich, Germany. June 22-26, 2009.

[AvUP5] Hongbin Li, Luis Almeida, Fausto Carramate, Zhi Wang, Youxian Sun. Using Low-Power Radios for Mobile Robots Navigation. FET 2009 – 8th IFAC Conference on

Fieldbuses and Networks in industrial and embedded systems. Ansan, Korea. May 20-22, 2009.

TUKL

[TUKL1] Ramon Serna Oliver, Gerhard Fohler, Probabilistic Estimation of End-to-End Path Latency in Wireless Sensor Networks, Proceedings of the Sixth IEEE International Conference on Mobile Ad-hoc and Sensor Systems (MASS09), Macau SAR, P.R.C, October 2009.

[TUKL2] Ivan Shcherbakov, Gerhard Fohler, An Efficient Operating System Abstraction Layer for Portable Applications in the Domain of Wireless Sensor Networks, Ramon Serna OliverPoster, Proceedings of The 7th ACM Conference on Embedded Networked Sensor Systems (SenSys '09), ACM, Berkeley, California, USA, November 2009.

Cantabria

[Cant1] Héctor Pérez Tijero, J. Javier Gutiérrez and Michael González Harbour. "Support for a real-time transactional model in distributed Ada". 14th International Real-Time Ada Workshop (IRTAW-14), October 7-9 in Portovenere, Italy

[Cant2] H. Pérez Tijero and J. J. Gutiérrez. "Experience in Integrating Interchangeable Scheduling Policies into a Distribution Middleware for Ada". SIGAda 2009 ACM Annual International Conference on Ada and Related Technologies: Engineering Safe, Secure, and Reliable Software. St. Petersburg, Florida, USA, November 1-5, 2009.

Catania

[CT1] L. Lo Bello, E. Toscano, “Coexistence issues of multiple co-located IEEE 802.15.4/ZigBee networks running on adjacent radio channels in industrial environments”, IEEE Transactions on Industrial Informatics, Special Section on Communication in Automation, Vol.5, N.2, pp., ISSN 1551-3203, IEEE Industrial Electronics Society, Piscataway, USA, May 2009.

[CT2] L. Lo Bello, E. Toscano , S. Vittorio , “A perspective on the IEEE 802.11e Protocol for the Factory Floor , in Dr. Vedran Kordic, *Factory Automation*, InTech, ISBN 978-953-7619-42-8 (in press).

[CT3] T. Sauter, J. Jasperneite, L. Lo Bello, “Towards New Hybrid Networks for Industrial Automation”, In Proceedings of the 14th IEEE International Conference on Emerging Technologies and Factory Automation, ETFA'09, Sept.22-26, 2009, Palma de Mallorca, Spain, ISBN 978-1-4244-2728-4, ISSN 1946-0759.

[CT4] M. Collotta, L. Lo Bello, E. Toscano, “A Proposal towards Flexible Wireless Communication in Factory Automation based on the IEEE 802.15.4 Protocol”, In Proceedings of the 14th IEEE International Conference on Emerging Technologies and Factory Automation, ETFA'09, Sept.22-26, 2009, Palma de Mallorca, Spain, ISBN 978-1-4244-2728-4, ISSN 1946-0759.

[CT5] F. Sgrò. L. Lo Bello, M. Lipoma, “A networked embedded computing platform for physical activity assessment”, IEEE/IES Conference on Human-Systems Interaction, HSI’09, Catania, 2009, ISBN: 978-1-4244-3960-7.

Pisa

[Pisa1] G. Cecchetti, A.L.Ruscelli, “Real-time support for HCCA function in IEEE 802.11e networks: a performance evaluation,” Special Issue of Wiley Journal of Security and Communication Networks on Security for QoS Assured Wireless Networks, to appear.

[Pisa2] Gianluca Franchino, Giorgio Buttazzo, and Tullio Facchinetti, "Token Passing Techniques for Hard Real-Time Communication", in Factory Automation, ISBN 978-953-7619-42-8, to appear.

[Pisa3] M. Di Natale, “What Can go wrong in CAN (timing analysis)”, SAE Conference 2009, 20-24 April 2009, Detroit MI

Catalonia

[Cat1] M. Velasco, P. Martí, J. Yépez, R. Villà and J.M. Fuertes. Schedulability Analysis for CAN-based Networked Control Systems with Dynamic Bandwidth Management. In 14th IEEE International Conference on Emerging Techonologies and Factory Automation (ETFA09), Mallorca, Spain, September 2009.

York

[York1] J. Tate, I. Bate, Tuning Complex Sensornet Systems Using Principled Engineering Methods, Proceedings of the 16th Annual IEEE International Conference and Workshop on the Engineering of Computer-Based Systems, pp. 275-284, 2009.

[York2] J. Tate, I. Bate, Sensornet Protocol Tuning Using Principled Engineering Methods, To Appear, The Computer Journal

[York3] J. Tate, B. Woolford-Lim, I. Bate, X. Yao, Comparing Design Of Experiments and Evolutionary Approaches To Multi-Objective Optimisation Of Sensornet Protocols, Proceedings of the 10th IEEE Congress on Evolutionary Computation, pp. 1137-1144, 2009.

[York4] J. Tate, I. Bate, Understanding Behavioural Tradeoffs in Large-Scale Sensornet Design, IEEE International Workshop on Quantitative Evaluation of Large-Scale Systems and Technologies, pp. 1085-1091, 2009.

[York5] J. Tate, I. Bate, An Improved Lightweight Synchronisation Primitive For Sensornets, Proceedings of the 6th IEEE International Conference on Mobile Ad-hoc and Sensor Systems, pp. 448-457, 2009.

[York6] J. Tate, I. Bate, Energy Efficient Duty Allocation Protocols For Wireless Sensor Networks, Proceedings of the 14th International IEEE Conference on Engineering of Complex Computer Systems, pp. 58-67, 2009.

Porto

[PO1] Anis Koubâa, Ricardo Severino, Mario Alves, Eduardo Tovar, “H-NAMe: A Hidden-Node Avoidance Mechanism for Wireless Sensor Networks”, 8th IFAC International Conference on Fieldbuses and Networks in Industrial and Embedded Systems (FET'09), Ansan, Republic of Korea, May 2009.

[PO2] A. Koubâa, R. Severino, M. Alves, E. Tovar, “Improving Quality-of-Service in Wireless Sensor Networks by mitigating hidden-node collisions”, IEEE Transactions on Industrial Informatics, Special Issue on Real-Time and Embedded Networked Systems, Volume 5, Number 3, August 2009.

[PO3] Ricardo Severino, Anis Koubâa, Mário Alves, Eduardo Tovar, “Demonstrating H-NAMe - A Hidden-Node Avoidance Mechanism for Wireless Sensor Networks”, Poster/Demos

Session of the First European TinyOS Technology Exchange (ETTX'09), Cork, Ireland, February, 2009.

[PO4] Manish Batsa, "Supporting Different QoS Levels in Multiple-Cluster Wireless Sensor Networks", MSc Thesis submitted in partial fulfillment of the requirements for the award of the Integrated Dual Degree in Computer Science and Engineering, Indian Institute of Technology (IIT) Roorkee, submitted October 2009.

Madrid (UC3M)

[UC3M1] Pablo Basanta-Val, Marisol García-Valls and Iria Estévez-Ayres. *No-Heap Remote Objects for Distributed Real-time Java* ACM Transactions in Embedded Computing Systems. Accepted for future publication.

[UC3M2] Pablo Basanta-Val, Marisol García-Valls, Iria Estévez-Ayres y J. Fernández-González. *Integración de capacidades de multiplexación en el conjunto de subprotocolos JRMP. Integrating Multiplexing Facilities in the Set of JRMP Subprotocols* IEEE América Latina (IEEE Latin America Transactions), ISSN 1548-0992. vol. 7(1), pp 107-113, March 2009. Electronic Edition. DOI: 10.1109/TLA.2009.5173472

[UC3M3] Pablo Basanta-Val, Marisol García-Valls and Iria Estévez-Ayres. *Simple asynchronous remote invocations for distributed real-time Java* IEEE Transactions on Industrial Informatics, vol 5 (3), pp. 289-298 ,Aug. 2009. Bibtex. DOI: 10.1109/TII.2009.2026271

-- The above are new references, not present in the Y1 deliverable --

2.3 Interaction and Building Excellence between Partners

Madrid (UC3M) and **Aveiro/UnivPorto** have been collaborating in the provision of real-time networking support to service-oriented middleware [Av+3][Av+4] and in the scope of the DREQUIEMI framework developed at UC3M to support distributed real-time Java applications, using principles from the FTT framework developed in Aveiro. Three informal meetings took place aside the progress meetings of the iLAND project, in which both teams participate. Moreover, Marisol Garcia-Valls, professor at UC3M, visited Aveiro to participate in a PhD thesis on dynamic QoS management using the FTT-SE protocol and attend a demo of the new Ethernet switch being developed by Aveiro within the HARTES project.

Mallorca and **Aveiro/UnivPorto** continued their collaboration towards the definition of flexible yet dependable mechanisms for distributed real-time systems and on the use of star topologies to boost robustness, particularly CANcentrate and ReCANcentrate for CAN networks [Av+2] [Av+3] [Av+4] [Av+5] [Av+7]. The team from Mallorca participated in the kick-off meeting of the HARTES project, in Aveiro, in which they participate to develop flexible fault-tolerant mechanisms for the new switch.

Pavia, **Aveiro/UnivPorto** and **Mälardalen** continued collaboration in the scope of automotive systems concerning the use of DC powerline networking technology to save cabling. Pedro Silva, a student from Aveiro, spent 4 months in Pavia carrying out experiments to characterize the datalink layer of Yamar DC powerline modems [Av+8][Av+9].

Aveiro/UnivPorto and **Mälardalen** followed their collaboration towards designing protocols to support compositionality in networked embedded systems exploring server-based CPU scheduling in networks. During this period the cooperation focused on the new Ethernet switch being developed in Aveiro within the HARTES project [Av+6]. This framework also involves collaboration with the team from **Mallorca** as well as with **CMU**.

Valencia (Alcoy branch) and **Aveiro/UnivPorto** continued the co-operation towards dynamic QoS management of industrial video surveillance systems [Av+1]. The result of this cooperation was included as a case study in the PhD thesis of Ricardo Marau, defended during this period in Aveiro.

Bilbao (EHU/UPV) and **Aveiro/UnivPorto** have been cooperating towards a more deterministic use of CORBA-RT by controlling the methods invocation instants using the FTT paradigm. Isidro Calvo, a professor from Bilbao, visited UnivPorto during this period to further discuss the associated scheduling model.

Aveiro/UnivPorto started a collaboration with **University of Pittsburgh** in the scope of the Reconfigurable and Adaptive TDMA protocol (RA-TDMA) developed previously in Aveiro to characterize the reconfiguration time upon the addition or removal of a node to/from the team (cluster). Frederico Santos, a PhD student from Aveiro, spent two weeks at UPitt to trigger such work.

Zaragoza (UniZar) and **UnivPorto** started a cooperation in this period in the scope real-time wireless communication for mobile robots. A PhD student from Zaragoza, Danilo Tardioli, spent 3 months at UnivPorto working on ways to introduce graceful degradation in a protocol designed within his work when in the presence of alien traffic.

TUKL, **Philips**, and **CSEM** have started work on timeliness issues for WSN, with a focus on accurate simulations [TPC1] [TPC2].

Catania hosted a visit from Prof. Tarek Abdelzaher from University of Illinois at Urbana Champaign (**UIUC**), USA, and is now setting up a collaboration.

Porto and **Pisa** continued the cooperation towards the implementation of the IEEE 802.15.4/ZigBee stack over the RTOS ERIKA [POc3] for WSNs. A student from the Indian Institute of Technology (IIT) Roorkee spent 6 months in **Porto** as a CISTER/ISEP researcher and built upon this joint work. He recently submitted and is up to defend his MSc Thesis [PO4].

Similarly, **Porto** and **Prague** continued their collaboration in the scope of Open-ZB.net - an open-source toolset for IEEE 802.15.4/ZigBee.

Pisa also continued its collaboration with the University of California at Berkeley (**UCB**) concerning automotive networks.

During the reporting period, the partners involved in this activity set up several **R&D project proposals** together with several **other academic and industrial partners**, which were submitted, either within the FP7 ICT, ARTEMIS and ITEA2 calls.

-- Changes wrt Y1 deliverable --

With respect to Y1, the same collaborations continued but new ones appeared, involving more organizations.

2.4 Joint Publications Resulting from these Achievements

Aveiro/UnivPorto, Valencia, Mallorca, Malardalen, Pavia

[Av+1] Javier Silvestre, Ricardo Marau, Paulo Pedreiras, Luis Almeida. *On-line QoS Management for Multimedia Real-Time Transmission in Industrial Networks*, IEEE Transactions on Industrial Electronics (to appear).

[Av+2] Manuel Barranco, Julian Proenza, Luis Almeida. *Quantitative comparison of the error-containment capabilities of a bus and a star topology in CAN networks*, IEEE Transactions on Industrial Electronics (to appear).

[Av+3] Manuel Barranco, Julian Proenza, Luis Almeida. *First quantitative results of the dependability improvement achieved by ReCANcentrate.* (Work-In-Progress paper) ETFA 2009, 14th IEEE Conference on Emerging Technologies and Factory Automation. Palma, Spain, 22-25 September 2009.

[Av+4] Pimentel, J.; Proenza, J.; Almeida, L.; Rodríguez-Navas, G.; Barranco, M.; Ferreira, J.. Dependable Automotive CAN Networks. N. Navet, F. Simonot-Lion *(eds.)* Handbook on Automotive Embedded Systems. CRC Press, 2009.

[Av+5] Manuel Barranco, Julian Proenza, Luis Almeida. *Boosting robustness in CAN systems with new star topologies: CANcentrate and ReCANcentrate*, IEEE Computer, 42(5): 66-73, May 2009.

[Av+6] R. Santos, A. Vieira, R. Marau, P. Pedreiras, A. Oliveira, L. Almeida, T. Nolte. Implementing Server-Based Communication within Ethernet Switches. CRTS 2009 – 2nd Workshop on Compositional Theory and Technology for Real-Time Embedded Systems (satellite of RTSS 2009), Washington DC, USA, December 1, 2009.

[Av+7] Manuel Barranco, David Gessner, Julián Proenza, Luís Almeida. Demonstrating the feasibility of media management in ReCANcentrate. (Work-In-Progress paper) ETFA 2009, 14th IEEE Conference on Emerging Technologies and Factory Automation. Palma, Spain, 22-25 September 2009.

[Av+8] Pedro Silva, Luis Almeida, Daniele Caprini, Tullio Facchinetti, Francesco Benzi, Thomas Nolte. Experiments on timing aspects of DC-Powerline communications. (Work-In-Progress paper) ETFA 2009, 14th IEEE Conference on Emerging Technologies and Factory Automation. Palma, Spain, 22-25 September 2009.

[Av+9] E. Bassi, F. Benzi, T. Facchinetti, L. Almeida, and T. Nolte, Powerline Communication in Electric Vehicles, IEMDC 2009 - IEEE Electric Machines and Drives Conference, Miami, USA, May, 2009.

Madrid (UC3M), UnivPorto, Madrid (UPM)

[UC+1] Iria Estévez-Ayres, Pablo Basanta-Val, Marisol García-Valls, Jesús A. Fisteus and Luís Almeida. *QoS-aware Real-Time Composition Algorithms for Service-Based Applications*. IEEE Transactions on Industrial Informatics, 5(3):278:288, August 2009.

[UC+2] Pablo Basanta-Val, Iria Estévez-Ayres, Marisol García-Valls, Luis Almeida, "A Synchronous Scheduling Service for Distributed Real-Time Java," IEEE Transactions on Parallel and Distributed Systems, 09 Jun. 2009. IEEE computer Society Digital Library. IEEE Computer Society, http://doi.ieeecomputersociety.org/10.1109/TPDS.2009.95

[UC+3] M. García-Valls, A. Alonso, and J. A. de la Puente. *Dynamic Adaptation Mechanisms in Multimedia Embedded Systems*. In Proc. of the 7th IEEE International Conference on Industrial Informatics. (IEEE INDIN 09). Cardiff, UK. 24-26 June 2009.

TUKL, Philips, CSEM

[TPC1] Jerome Rousselot, Jean-Dominique Decotignie, Marc Aoun, van der Stok, Peter, Ramon Serna Oliver, Gerhard Fohler, Accurate Timeliness Simulations for Real-Time Wireless Sensor Networks, European Modelling Symposium 2009, Athens, Greece, November 2009.

[TPC2] Anthony Schoofs, Marc Aoun, Peter van der Stok, Julien Catalano, Ramon Serna Oliver, Gerhard Fohler, A Framework for Time-Controlled and Portable WSN Applications, Proceedings of the 1st International Conference on Sensor Networks Applications, Experimentation and Logistics (SENSAPEAL09), SPRINGER, Athens, Greece, September 2009.

Pisa, Evidence, UCB, Porto, Prague

[Pis+1] Haibo Zeng, Marco Di Natale, Paolo Giusto Alberto Sangiovanni-Vincentelli “Statistical Analysis of Controller Area Network Message Response Times”, SIES Conference, Lausanne July 8-10, 2009 (winner of best paper award).

[Pis+2] Haibo Zeng, Wei Zheng, Marco Di Natale, Arkadeb Ghosal, Paolo Giusto Alberto Sangiovanni-Vincentelli “Scheduling the FlexRay Bus Using Optimization Techniques”, 46th DAC Conference, San Francisco, CA July 26-31, 2009.

[Pis+3] W. Li, M. Di Natale, W. Zheng, P. Giusto, A. Sangiovanni-Vincentelli and S.A. Seshia, “Optimizations of an Application-Level Protocol for Enhanced Dependability in FlexRay”, DATE Conference, April 20-24 2009, Acropolis, Nice, France.

[Pis+4] Mangesh Chitnis, Yao Liang, Jiang Yu Zheng, Paolo Pagano, Giuseppe Lipari, "Wireless Line Sensor Network for Distributed Visual Surveillance", in Proceedings of 6th ACM PE-WASUN 2009, Tenerife, Canary Islands, Spain, October 2009

[Pis+5] Paolo Pagano, Francesco Piga, Giuseppe Lipari, Yao Liang, “Visual tracking using sensor networks”, Proceedings of the 2nd International Conference on Simulation Tools and Techniques (SimuTools 2009), March 2009.

[Pis+6] C. Nastasi, P. Pagano, M. Marinoni, G. Lipari, F. Focacci, P. Gai, S. Mannori, R. Bucher, “Model based Real-Time networked applications for Wireless Sensor Networks”, 7th Annual IEEE International Conference on Pervasive Computing and Communications (PerCom), Demonstration Session, Mar. 2009.

[Pis+7] P. Pagano, F. Piga, Y. Liang, “Realtime MultiView Vision Systems” using WSNs, 24th Annual ACM Symposium on Applied Computing (SAC), March 2009.

[Pis+8] M. Chitnis, P. Pagano, G. Lipari, and Y. Liang, "A Survey on Bandwidth Resource Allocation and Scheduling in Wireless Sensor Networks ." 12th International Conference on Network-Based Information Systems. Indianapolis, USA.Aug. 19 to 21, 2009.

[Pis+9] P. Pagano, M. Chitnis, G. Lipari, C. Nastasi, and Y. Liang, “Simulating Real-Time Aspects of Wireless Sensor Networks”, EURASIP Journal on Wireless Communications and Networking, Special issue on Simulators and Experimental Testbeds Design and Development for Wireless Networks, to appear.

[POc1] P. Jurcik, A. Koubâa, R. Severino, M. Alves, E. Tovar, Real-Time Communications over Cluster-Tree Sensor Networks”, under revision process in an international journal.

[POc2] Ricardo Severino, Anis Koubâa, Petr Jurčik, Mário Alves, Eduardo Tovar, “An overview of Open-ZB.net - an open-source toolset for IEEE 802.15.4/ZigBee”, Poster Session of the First European TinyOS Technology Exchange (ETTX'09), Cork, Ireland, February, 2009.

[POc3] P. Pagano, M. Chitnis, A. Romano, G. Lipari, R. Severino, M. Alves, P. Sousa, E. Tovar, "ERIKA and OpenZB: an implementation for real-time wireless networking", 24th ACM Symposium on Applied Computing (SAC 2009), Poster Session, Honolulu, Hawaii, March, 2009.

-- The above are new references, not present in the Y1 deliverable --

2.5 Keynotes, Workshops, Tutorials

Invited talk: Mário Alves, *Quality of Service in Wireless Sensor Networks: towards the eQualiSer…*
Event: 1st Int. School on Cyber-Physical and Sensor Networks - SensorNets 2009
Monastir, Tunisia – 17-21 December 2009

Addresses the issues behind the support for Quality of Service in WSNs.
http://www.sensornets-school.org

Invited talk: Marisol García-Valls, ***Middleware for Avionics***
Event: Master in Avionic Systems Integration 2008-2009
Airbus Center, *Getafe, Madrid, Spain – 28th October 2009*

Addresses the issues on integrating real-time middleware in ground segments for control of aircraft missions, areas in wich **UC3M** is performing active research.

Invited talk: Luis Almeida, *Mobile Cyber-Physical Systems*
Event: ArtistDesign Summer School in Europe 2009
Autrans, France – 7-11 September 2009

Addresses the issues behind the coordination of small teams of mobile sensing/actuating agents focusing on the wireless communication issues researched by Aveiro and now UnivPorto.
http://www.artist-embedded.org/artist/Programme,1636.html#Almeida

Invited talk : Luis Almeida, *Taming the Flexibility versus Safety Challenge in Distributed Embedded System**s***
Conference name: Seminar at the 1st tubs.CITY Symposium, Tech. Univ. Braunschweig
Braunschweig, Germany – 1-3 July 2009

Focuses on the flexibility versus safety conflict and addresses several perspectives of flexibility as well as the techniques that were developed in Aveiro to support them.
http://city.tu-braunschweig.de/index.php/en/events/symposium-2009/workshops/embedded-communication-

Invited talk : Luis Almeida, *Networks and Middleware*
Event: Seminar at European Community Embedded Systems Unit
Brussels, Belgium – 18-19 June 2009

Focuses on the flexibility versus safety conflict and addresses several perspectives of flexibility as well as the techniques that were developed in Aveiro to support them.
http://www.artist-embedded.org/artist/Programme,1652.html

Invited talk : Luis Almeida, *A Dynamic Scheduling Approach to Designing Flexible Safety-Critical Systems*
Institution: Seminar at the CISTER research Unit, Polytechnic Institute of Porto
Porto, Portugal – 5 June 2009

Focuses on the flexibility versus safety conflict and addresses mainly the scheduling issues. http://www.cister.isep.ipp.pt/activities/SEMINARS/%28S%2825ohbe55j1gkob55jmibsx45%29%29/Distinguished.ashx

Invited talk : Luis Almeida, *Has the time come to flexible safety-critical systems?*
Event: Final DySCAS Workshop (FP6-STREP project)
Brussels, Belgium – 18 February 2009

Raises awareness to the issues related with the flexibility versus safety conflict, the benefits that are associated with a combination of both aspects and the challenges in achieving such combination.
http://www.dyscas.org/final_workshop.htm

Invited talk : Luis Almeida, *Challenges of flexible real-time communication*
Institution: Doctoral Program, Dep. of Automatic Control and Systems Engineering, University of the Basque Country
Bilbao, Spain – 21 January 2009

States the benefits that are inherent to flexible communication with timing guarantees and the challenges that need to be overcome to achieve it. It is a re-edition of the talk with the same title given at the Artist2 Summer School in Europe 2008, at Autrans.

Workshop : SensorNets 2009 – 1st Int. School on Cyber-Physical and Sensor Networks
Monastir, Tunis – December 17-21, 2009

This is a three and a half days school focusing on sensor networks and involving a broad set of researchers from that specific community. In particular it has a substantial involvement of the team from **Porto** with the collaboration from other teams within and outside Europe.
http://www.sensornets-school.org/

Workshop: APRES 2009 – 2nd Workshop on Adaptive and Reconfigurable Embedded Systems
Conference name : within the ESWEEK 2009 – 2nd Embedded Systems Week
Grenoble, France – October 11, 2009

This workshop was organized jointly with the Transversal Activity on Design for Adaptivity and with the cooperation of **UnivPorto**, **Mallorca**, **Lund**, University of Pennsylvania - **UPenn** (US) and University of **Waterloo** (Canada). The fact that it is referred in this deliverable reflects the predominance of networking and middleware issues. The materials of the workshop are available online in the workshop website. The proceedings of the workshop were also published as a special section of ACM's **SIGBED Review**
http://www.artist-embedded.org/artist/Overview,1765.html

Workshop : RTN 2009 – 8th Workshop on Real-Time Networks
Conference name : ECRTS 2009 – 21st EUROMICRO Conference on Real-Time Systems
Dublin, Ireland – June 30, 2009

This workshop was the 8th in its series and focused on the current technological challenges of developing communication infrastructures that are real-time, reliable, pervasive and interoperable. It provides a relaxed forum for discussing those challenges taken has basis a restricted set of papers and a couple of invited keynotes.
http://www.hurray.isep.ipp.pt/rtn09/index.php

Tutorial : Luis Almeida, *Real-Time Communication for Embedded Systems*
Institution: Course at ENSIAS, Ùniversity Mohammed V
Rabat, Morrocco – 22-24 October, 2009

18h course covering the concepts, techniques, technologies and applications of real-time networks.

Tutorial : Luis Almeida, *Real-Time Communication in Embedded Systems*: *Techniques, Technologies and Applications*
Event: ArtistDesign Summer School in China 2009
Beijing, China – 20-24 July, 2009

6h course covering the techniques, technologies and applications of real-time networks with a focus on traffic scheduling issues.
http://www.artist-embedded.org/artist/Overview,1630.html

Tutorial : Luis Almeida, Paulo Pedreiras, *Networks for Embedded Control Systems*
Event: ArtistDesign Graduate Course on Embedded Control Systems: Theory and Practice
Pisa, Italy – 8-12 June, 2009

4h lecturing covering the techniques, technologies and applications of real-time networks focusing on the protocol stack, plus 1h laboratory for hands-on session.
http://www.artist-embedded.org/artist/Overview,1673.html

Tutorial : Mário Alves, *The wireless sensor networks standards and COTS landscape: can we get QoS and "calm technology"?"*
Event: 6th European Conference on Wireless Sensor Networks - EWSN'09
Cork, Ireland – 11 February, 2009

http://ewsn09.v6testbed.net.
http://www.ewsn.org/tutorial.html
http://artwise.cister-isep.info/publications.php

-- The above is new material, not present in the Y1 deliverable --

3. Milestones, and Future Evolution

3.1 Problem to be Tackled over the next 12 months (Jan 2010 – Dec 2010)

For the next 12 months period, this activity will continue pursuing its objectives as stated in Section 1.4. In particular, we expect to pursue the following lines:

- *Further analysis of network induced delays in diverse domains, from WSNs to NoCs as well as specific architectures, protocols and or traffic models.*
- *Improvements in the timeliness of the communication in WSNs by means of architectural and protocol solutions while reducing resource requirements (e.g. energy, memory and CPU) and supporting scalable data aggregation.*
- *Support for dynamic reconfiguration in wireless networks arising from mobility as well as changes in the set of active nodes and provision of graceful degradation in the timeliness and reliability of data delivery.*
- *Architectures and protocols for NESs to support efficient QoS adaptation, dynamic reconfiguration, composability and higher robustness with respect to the coverage of assumptions on the desired behaviour of nodes and environment.*
- *Exploration of new media for NESs, particularly DC powerline, and its use in specific domains such automotive and aerospace, and analyse its combination with star/tree topologies.*
- *Analysis of specific application domains, including assessment of operational environments, suitability of protocols, deployment issues, integration in larger systems.*

-- Changes wrt Y1 deliverable --

Minor changes with respect to Y1 to include an explicit reference to the work concerning mobility issues in wireless networks and the growing attention dedicated to specific application domains.

3.2 Current and Future Milestones

Year 1

• Contributions to the Zigbee specification **(achieved)**

• Educational tools supporting teaching of wired/wireless networked embedded systems **(achieved)**

• Taxonomy of WSN and MANET within real-time applications **(partially achieved).**

• Taxonomy of flexibility within distributed real-time applications **(partially achieved).**

Year 2

- ***Summer school on Real-Time Networks.***

Achieved. **Porto** is involved in the organization of the SensorNets 2009 school (http://www.sensornets-school.org/) dedicated to Cyber-Physical Systems and Sensor Networks and also involving other teams. Moreover, other similar activities were organized

along the period, namely the ArtistDesign Summer School in China (http://www.artist-embedded.org/artist/Overview,1630.html) and the ArtistDesign Graduate Course on Embedded Control Systems (http://www.artist-embedded.org/artist/Overview,1673.html), both covering the topic of Real-Time Networks by **UnivPorto** and **Aveiro**. The ArtistDesign Summer School in Europe (http://www.artist-embedded.org/artist/Programme,1636.html) also included several talks related to that topic.

- ***Further educational tools to support teaching networked embedded systems***

Achieved. **Aveiro**, **UnivPorto** and **Pavia**, with Pavia leading, have continued with the series of Student Design Competitions in the scope of the IEEE Real-Time Systems Symposium. This year, this competition called CyberRescue@RTSS2009 focuses on the real-time control of a team of mobile autonomous agents, which involves, among other things, the development of an ad-hoc wireless communications protocol and an adequate middleware. All the necessary tools are available on-line (http://robot.unipv.it/cyberrescue-RTSS09/) and the simulator became this year an open software project (http://sourceforge.net/projects/cpss/files/).

- ***Contributions to communication protocols, their application and analysis***

Achieved. It is naturally a target of the activity to carry out the contributions referred in this milestone. In the current period many contributions have been made, which were described in Section 2.1.

- **Taxonomy of WSN and MANET within real-time applications.**

Partially achieved. This taxonomy surveys the existing protocols, their features and limitations, as well as the respective middleware for application development in the scope of WSN and MANET. It is still an on-going effort that, for the sake of thoroughness, will be continued during Year 3. During the current period a draft was produced based on a collaborative document while a wiki is being prepared to support the completion of the process.

- **Taxonomy of flexibility within distributed real-time applications.**

Partially achieved. This taxonomy surveys the several perspectives of the concept, from design flexibility to configuration flexibility, operational flexibility etc, but also within the scope of real-time distributed applications with more or less criticality. It was found, however, that it was more adequate to merge this effort with a similar one being developed within the Transversal Activity on Design for Adaptivity, which is also on-going, based on a wiki, and will be continued during Year 3.

Future milestones

Continue the current efforts and achieve the following:

- ***Summer school on Real-Time Networks.***
- ***Further educational tools to support teaching networked embedded systems***
- ***Contributions to communication protocols, their application and analysis.***
- ***Taxonomy of WSN and MANET within real-time applications.***
- ***Taxonomy of flexibility within distributed real-time applications (to be continued jointly with the Transversal Activity on Design for Adaptivity).***

3.3 Main Funding

The ArtistDesign NoE funds integration and building excellence with the partners, and with the European research landscape as a whole. Beyond this "glue" for integration and excellence, during Year2 this activity has benefited from direct funding from:

- **iLAND – mIddLewAre for deterministic dynamically reconfigurable NetworkeD embedded systems.**
  (2009 – 2012), supported by the European Community through the Joint Undertaking ARTEMIS. 9 organizations incuding **UnivPorto** and **Madrid**. Aims at developing a middleware targeting dynamically reconfigurable and adaptive systems.
  http://weblink.weblink.weblink/webpage
- **INDEXYS – INDustrial EXploitation of the genesYS cross-domain architecture**
  (2009-2011) supported by the European Community through the Joint Undertaking ARTEMIS. 10 organizations incuding **NXP** and **TUKL.** Aiming at in-vehicular networks with focus on FlexRay.
  http://www.indexys.eu/
- **HaRTES: Hard Real-Time Ethernet Switching**
  (2009 – 2011), supported by the Portuguese Government through Fundação para a Ciência e Tecnologia PTDC/EEA-ACR/73307/2006 and involving **Aveiro**, **UnivPorto** and **Mallorca**. Aims at the design of a new type of Ethernet Switches that include flexible transmission control capabilities together with enhanced traffic classification and filtering that boost safety and timeliness while maintaining operational flexibility.
  http://www.ieeta.pt/lse/hartes/
- **ACORD - Adaptative Coordination of Robotic Teams**
  (2008 – 2009), supported by the Portuguese Government through Fundação para a Ciência e Tecnologia PTDC/EIA/70695/2006 and involving **Aveiro** and **UnivPorto**. Includes flexible wireless communication strategies that cope with dynamic team composition, heterogeneity of team members, dynamic role assignment, while trying to provide some level of real-time behaviour.
  https://193.136.27.99/Members/info/niad-r-info/acord-adaptative-coordination-of-robotic-teams
- **FlexWARE: Flexible Wireless Automation in Real-Time Environments**
  ICT 7FP STREP project involving **Catania** and aiming at the implementation of a novel platform for the support of real-time communication over Wireless Local Area Networks based on the IEEE 802.11 standard.
  http://weblink.weblink.weblink/webpage
- **IPERMOB: Pervasive and Heterogeneous Infrastructure to Control Urban Mobility in Real-time**
  Italian project (Regione Toscana) project involving **Pisa** and **Evidence** aiming at the implementation of an infrastructure to monitor and control mobility in urban centers.
  http://www.ipermob.org
- **CANbids: CAN-based infrastructure for dependable systems**
  (2009-2011) Spanish project (PNIF, DPI2008-02195) project involving **Mallorca** and **UnivPorto** aiming at using operational flexibility and star topologies to build infrastructures that are highly-dependable but with low cost.
- **WASP: Wirelessly Accessible Sensor Populations**
  (2006-2010) FP6-IST (IST- 034963) project involving **TUKL** and **CSEM** (among 18 partners) aiming at covering all the layers in WSNs, from hardware to the data dissemination and self-organization, to facilitate their deployment.

-- Changes wrt Y1 deliverable --

List updated, finished projects removed, new projects added. In particular, three new projects with substantial industrial involvement were added.

4. Internal Reviewers for this Deliverable

- **Jean-Dominique Decotignie** (CSEM, Lausanne, Switzerland)
- **Giorgio Buttazzo** (SSSA, Pisa, Italy)