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SOCRADES

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Service-Oriented Cross-layer infRAstructure for Distributed smart Embedded devices

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Short document description:	Based on the initial state-of-the-art analysis, done in D1.1, and the trend screening reports 1 (D1.3) and 2 (D1.4) this document describes the progress in state-of-the-art discovered till month 37 of the project duration.		
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[2] As defined in the DoW
[3] Scheduled date for approval

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Executive Summary

This deliverable is aimed to complement and reinforce gathered information regarding state-of-the-art and trends in SOCRADES related technologies. The initial state-of-the-art analysis was presented in several initial documents as there are D1.1, D1.3, D1.4, D3.1, D4.1 or D7.1. These referred documents should be considered along with this report to obtain an overall view of SOCRADES project starting up conditions and current situation. All state-of-the-art related deliverables as well as those related to trend screening are fed beck to the individual WP's as a basis for the alignment of the work done to the current scientific and market situation.

From the trend point of view, not all technologies and methods can be equally treated, as the representative time frames of each evolution, interdependencies, emerging features and progress indicators are quite different in some cases, closely related in others. Some of the technologies described here will succeed in their evolution and application in industrial environments, some others will be abandoned. The forecasting of the future of ICT's related to SOCRADES is not the aim of this document, but it is difficult to avoid entering evaluation concerning some of them. Consequently this report is considered for the work done in Task 10.3.

The document is structured into 8 sections, each of them dedicated to another technological field. Each section is related to a single section of D1.1 and its Annex.

Section 1 is aimed at providing an update of the state-of-the-art and trend description on middle ware concepts and solutions followed by section 2 providing the latest trends on agent-based control. The deliverable proceeds with the trends in service oriented architectures (section 3) to update the common understanding of the subject to the entire project team. Whereas section 4 is dedicated to the trends in networked control (related to WP4), section 5 describes the progress discovered in wireless technologies and sensor networks. Section 6 describes what is going on related to device profiles. The last two sections of this deliverable describe the ongoing trends in engineering of distributed systems and business process integration.

The structure of each chapter is first introduced by an overview of the technical progress discovered related to the selected technology, followed by a description of the process and its relation to the SOCRADES approach. Finally the relevant references are provided.

Deliverable D1.5 is a collection of contributions from the experts involved in the project distributed across the different work packages. It shows therefore an update of the state of the art at the current stage of the project. This deliverable is passed back to the technical WPs as well as to the project management to support supervision and evaluation of the projects progress.

1. Distributed control platforms

To overcome limitations of PLC-based automation technology and to meet requirements for more efficient manufacturing and logistics, there is a strong demand for research and technology development on "Next generation distributed embedded automation and control" focussed on issues like flexibility, scalability, modularity, decentralised intelligence, cooperative control and decision making, adaptability, improved fault-tolerance, quick and easy maintenance, multi-level communication, fast configuration and reconfiguration, or a seamless interaction of embedded systems across wired as well as wireless networks.

In this context many RTD activities have been recognised in the past with special regard to advanced distributed control systems, middleware solutions, and new control architectures based on distributed intelligence, but also to engineering methods for distributed systems in terms of reconfiguration, adaptation, and reuse of IPMCS (industrial process measurement and control systems).

Currently we see this work going on, but it is complemented by newly started research and development activities focussed on:

- large scale distributed control applications addressing model-based predictive control in combination with hierarchical/ distributed automation system set-ups
- coordination control for distributed systems
- encapsulation of subsystems in automation components and integrating seamlessly into more abstract levels of distributed control architectures,
- distributed wireless shop floor sensing, monitoring and control to support real time decision making in manufacturing,
- decentralised and wireless control of large scale systems, and
- system engineering by provision of a model-driven design method for embedded control and diagnostics.

1.1. Description of new solutions / progress and relation to SOCRADES

To cope with complex dynamics of multiple subsystems and mutual influences of local control decisions with long-range effects, the **HD-MPC** project intends to develop new and efficient methods and algorithms for distributed and hierarchical model–based predictive control of large-scale network systems with embedded controllers. Core element is a multi-level model of the system capable of determining optimal control signals while the controllers involved operate along several time scales and at different control levels. Coordination and cooperation between the controllers, both within and across the control levels, is addressed by the research work. To react adaptively is achieved through the use of a model-based approach, which will allow the controller to predict the effects of future control actions on the system, and to take external inputs and demands into account. Massive parallel computation will result in efficient and scalable control methods that are one or more orders of magnitude larger than what current methods can handle. Online and real-time constraints are considered.

The **CON4COORD** project work is focussed on control synthesis and design. Specially addressed is the control synthesis at the global level. As control problems cannot be solved using local control laws exclusively it is necessary to have a control law also at the global level of control. This is called "Coordinator" of the distributed system. The coordinator receives partial information from all subsystems and is able to facilitate cooperation between local subsystems. As the control of distributed systems will be performed via a communication network, beside this coordination aspect it is to consider that the control and communication systems are uncertain due to constraints given by the unreliability of information

during communication, limited communication channel capacity, and delayed arrival of the information. The project will cope with those problems in detail through special research.

The **CHAT** project aims at tackling the supervision and control of larger and more complex automated industrial plants. The idea is to push the frontier of control decentralisation much further. This will be achieved by use of an embedded control design space, where fundamental research questions on the performance of subsystems with a given quality of networked control can be formalised and investigated. Goal is to encapsulate subsystems in automation components integrating seamlessly into more abstract levels of the distributed control architecture.

DISC is a project which will focus research and technology development on supervisory control of distributed systems by means of a control agent that observes the current state of the plant and selects actuators that can control the execution of events in order to meet the specifications. However, problems occur in the frequent detection of events by sensors and limited bandwidth for the exchange of information between different agents. Therefore state estimation and fault diagnosis will be addressed simultaneously by use of computer-assisted methods relying on discrete-event driven models and reference models such as automata and Petri nets. Expected outcome of the project are new tools for modelling, simulation and supervisory control design.

The **WIDE** project concentrates on advanced control and real-time optimisation of large scale and spatially distributed systems based on distributed model predictive control and wireless sensor feedback. Proposed is a new engineering approach to the design of scalable model-based predictive controllers that optimise operational efficiency under resource and safety constraints and use of wireless sensor networks for closing the control loops. Outcome is a network of MPCs to achieve best performance of the system with integrated real-time optimisation. The scalability and re-configurability of the proposed solution contribute to the overall productivity and reduce installation time and costs.

Project goal of the **MEDEIA** project is to reduce the system design by a new system engineering approach (meta-design architecture), which allows a model-driven component-based development of embedded control and diagnostics. Core component is an automatic, embedded and platform-specific code generation for the deployment of control software to heterogeneous automation hardware. In this context main idea is to put a common element, the so called "Automation Component (AC)", in between the specification and the implementation element of an automation system implementation. The AC represents a combination of embedded hardware and software and is described in appropriate models.

The description of new approaches, concepts and technical solutions in the DCS domain has only indirect impact on the achievements of the SOCRADES project. Of relevance might be approaches related to the communication across wireless and wired networks, solving of real-time constraints in closed loop control, scalability and re-configurability, as well as system engineering aspects.

1.2. References

[1-1] A. Zoitl, "Real-time Execution for IEC 61499", ISA 2009, ISBN: 978193439-4274; http://www.isa.org/

[1-2] T. Strasser, M. Rooker, I. Hegny, M.Wenger, A. Zoitl, L. Ferrarini, A. Dede and M. Colla, "A Research Roadmap for Model-Driven Design of Embedded Systems for Automation Components", Proceedings of the 7th IEEE International Conference on Industrial Informatics (INDIN'09), June 23-26, 2009, Cardiff , Wales, United Kingdom

[1-3] M. Colla, T. Leidi and M. Semo, "Design and Implementation of Industrial Automation Control Systems: a Survey", Proceedings of the 7th IEEE International Conference on Industrial Informatics (INDIN'09), June 23-26, 2009, Cardiff , Wales, United Kingdom

[1-4] L. Ferrarini, A. Dedè, P. Salaün, T. Dang and G. Fogliazza, "Domain Specific Views in Model-driven Embedded Systems Design in Industrial Automation", Proceedings of the 7th IEEE International Conference on Industrial Informatics (INDIN'09), June 23-26, 2009, Cardiff , Wales, United Kingdom

[1-5] M. Wenger, A. Zoitl, C. Sünder and H. Steininger, "Transformation of IEC 61131-3 to IEC 61499 based on a model driven development approach", Proceedings of the 7th IEEE International Conference on Industrial Informatics (INDIN'09), June 23-26, 2009, Cardiff , Wales, United Kingdom

[1-6] T. Strasser, M. Rooker, A. Zoitl, I. Hegny, "Modellbasierte Entwicklung von eingebetteten Systemen in der Automatisierungsindustrie", Proceedings of the International Forum Mechatronik 2009 (IFM'09), November 10-11, 2009, Linz, Austria

[1-7] M. Hofmann, L. Hundt, T. Fuchs, "Seamless Engineering for Distributed Control Systems - An Approach for Virtual Automation Networks", IEEE International Conference on Industrial Technology, ICT 2009, 10-13 February, Melbourne, Australia, 2009, ISBN: 978-1-4244-3507-4

1.2.1. List of conferences covering relevant topics

Acronym	Description	Contact
EFTA 2009	14th IEEE International Conference on Emerging Technologies and Factory Automation, Sept 22-26, 2009, Mallorca/Spain	**http://etfa2009.org/**
ISA EXPO 2009 .	ISA EXPO Technical Conference, Oct 6-8, 2009, Reliant Center, Houston Texas/USA	**http://www.isa.org/expotemplate.cfm**

1.2.2. Relevant product announcements or links to company statements

Company name	Product name and description	Contact
ABB	ABB 800xA	http://www.abb.com/product/ge/9AAC115756.aspx
Siemens	Simatic PCS 7	http://www.automation.siemens.com/w2/automation-technology-distributed-control-system-simatic-pcs-7-1014.htm
Honeywell	Experion LS	www.honeywell.com/ps
Yokogawa	Centum CS; Centum VP	http://www.yokogawa.com/dcs/centumvp/dcs-vp-index-en.htm
Emerson Process Management	DELTA V	http://www.yokogawa.com/dcs/centumvp/dcs-vp-index-en.htm

1.2.3. Relevant projects

Acronym	Title	Status and results	Contact
HD-MPC	Hierarchical and distributed model predictive control of large scale systems	Start: Sept 2008 Duration: 36 months INFSO-ICT-223854	TU Delft; Delft B. DeSchutter Tel.: +31-15-2785113
CON4COORD	Control for coordination of distributed systems	Start: May 2008 Duration: 36 months INFSO-ICT-223844	Stichting Centrum voor Wiskunde en Informatica, Amsterdam Jan .H. Van Schuppen Tel.: +31-20-5924085
WIDE	Decentralised and wireless control of large scale systems	Start: Sept 2008 Duration: 36 months INFSO-ICT-224168	Univ. Degli Studi di Siena, Italy Alberto Bemporad Tel.: +39-057-723463
CHAT	Control of heterogeneous systems: technologies for scalability, reconfigurability and security	Start: Sept 2008 Duration: 36 months INFSO-ICT-224428	Univ. di Pisa, Italy Antonio Bicchi Tel.: +39-050-221705
DISC	Distributed supervisory control of large plants	Start: Sept 2008 Duration: 36 months INFSO-ICT-224498	Univ. Degli Studi di Cagliari, Italy Alessandro Giua Tel.: +39-070-675575
MEDEIA	Model-driven embedded system design for the industrial automation sector	Start: Jan 2008 Duration: 36 months INFSO-ICT-211448	PROFACTOR, Steyr, Austria Dr. Th. Strasser Tel.: +43-7252-885-309

1.2.4. Network activities

Acronym	Subjects covered	Status and results	Contact
O³Neida	Network of networks focused on fostering distributed industrial automation based upon open standards	RTD project, Standardisation	http://www.oooneida.org/index.html

2. Agent-based control

This section describes shortly the progress of the state-of-the-art discovered in relation to the topic of agent-based control.

2.1. Overview of progress discovered

During the last screening period, it was discovered that most of the progress carried out in the field of agent-based control and its connections with SOA technologies, was focused towards standardization efforts. Apparently, the research and industry communities have started to realize the benefits of integrating Multi-Agent Systems (MAS) and SOA. However, it is also clear that the first step that deserves attention is to achieve the standardization in the development of agent-oriented systems; i.e., not only from the conceptual point of view, but also from the implementation perspective. After this is accomplished, then it will be possible to include all the necessary elements for a complete integration with SOA.

2.2. Description of new solutions / progress and relation to SOCRADES

2.2.1. Standardization

The Foundation for Intelligent Physical Agents (FIPA), which is the organization in charge of promoting the standardization of agents and agent-based systems, is now trying to push the standards into the context of software development. For this reason, they have created two working groups:

- *Application Specification Working Group* [AS WG], which will be in charge of:
  - Specifying a common structure for specifications at the application level.
  - Promoting the design and development of application specifications, in any situations where agents are used.
- *Design Process Documentation and Fragmentation* [DPDF WG], which will be in charge of:
  - Identifying the most suitable process meta-model and notation for engineering processes.
  - Defining a proper template for the description of agent-oriented design processes.

The creation of these working groups may impact future developments of the SOCRADES architecture. From the perspective of agent-based systems, whenever a new system is created, it has to be designed from scratch since every component (agent) may have a completely different role for different applications. In the case of SOCRADES architecture, the agent-based control has been mainly used for implementing the decision-making component; and even though, a lot of efforts have been put in trying to make the system as generic as possible, this has not been completely achieved. If the SOCRADES architecture is going to aim at solving integration problems in environments with multiple devices or equipment, and with different control applications, thus the unification of application specifications and a design methodology will be very beneficial.

Two more standardization efforts parallel to the working groups created by FIPA, are the ones driven by the Object Management Group (OMG) under the umbrella of the Agent Platform Special Interest Group. In this sense, OMG has created two Request For Proposal (RFP):

- *Agent Metamodel and Profile* [AMP-RFP], this document solicits proposals for extending current UML modelling capabilities in order to include descriptions applicable to agents and agent-based software. In particular of interest for SOCRADES are the following points:
  - Clarification of semantics related to modelling of agents.
  - Enabling agent model interchange between tools via XML.
  - Facilitate the modelling of peer-to-peer, grid, and cloud computing, and other technologies in terms of a collection of agents.

- *Event Metamodel and Profile* [EMP-RFP], this document solicits proposals for extending current UML modelling capabilities in order to include descriptions applicable to the monitoring, detection, analysis, aggregation, and processing of events that are commonly handled by agents. In particular of interest for SOCRADES are the following points:
  - Clarification of semantics related to modelling of events.
  - Enabling event model interchange between tools via XML.

These RFP will also affect the future acceptance of SOCRADES architecture, specifically at the engineering level. If future development tools are able to integrate modelling capabilities for agents and events, then the creation of SOA-based engineering tools with similar capabilities will be greatly facilitated.

Another area in which FIPA has been working together with OMG is in the integration of their standards with SOA technologies. It is known that there is a standardization proposal called SOA-Pro (UML Profile and Metamodel for Services) [UPMS] where descriptions of agents linked to an SOA standard are mentioned; unfortunately, the documentation is only accessible to committee members so it was not possible to get more information.

2.2.2. Tools

Regarding new tools for developing agent-based systems, it was found that Comet Way has released a newer version (V3.0) of their open source Java-based distributed component framework for deploying agent applications. This development tool is not very well-known, but still the company has continued to create new versions with support for some embedded devices, including management of web-based (HTTP) and email-based (SMTP and POP3) applications, as well as connectivity with databases (JDBC and XML). From the SOCRADES perspective, the main interest on following the evolution of this kind of tools is to pinpoint any developments that, in the future, could help integrating the agent-based decision-making system developed under SOCRADES into embedded devices.

2.3. References

2.3.1. List of conferences covering relevant topics

Acronym	Description	Contact
AAMAS 2009	8th International Conference on Autonomous Agents and Multiagent Systems 2009, Budapest, Hungary.	
HOLOMAS 2009	4th International Conference on Industrial Applications of Holonic and Multi-Agent Systems 2009, Linz, Austria.	
AAMAS 2010	9th International Conference on Autonomous Agents and Multiagent Systems 2010, Toronto, Canada	Sandip Sen (sandip-sen@utulsa.edu), Michael Luck (michael.luck@kcl.ac.uk)

2.3.2. Relevant product announcements or links to company statements

Company name	Product name and description	Contact
Comet Way	Comet Way Java Agent Kernel. A small, open source distributed	info@cometway.com

	Java agent platform for embedded, mobile and smart devices with a built-in web server and SMTP server.	

2.3.3. New version of relevant specifications, RFCs, standarditation activities

Reference	Document Title and URL	Revision
AS WG	FIPA Application Specifications Working Group. http://www.fipa.org/subgroups/AS-WG-docs/AS_WG_Charter.doc	
DPDF WG	FIPA Design Process Documentation and Fragmentation Working Group. http://www.fipa.org/subgroups/DPDF-WG-docs/DPDF_WG_Charter.pdf	
AMP-RFP	OMG Agent Metamodel and Profile. http://www.omg.org/cgi-bin/doc?ad/2008-09-05	
EMP-RFP	OMG Event Metamodel and Profile. http://www.omg.org/cgi-bin/doc?ad/2008-09-15	
UPMS	SOA-pro UML Profile and Metamodel for Services. http://www.omg.org/cgi-bin/doc?ad/2008-11-01	

3. Service-Oriented Architectures for Devices

3.1. Overview of progress discovered

There are several activities in this domain described under [3-2].

3.2. Description of new solutions / progress and relation to SOCRADES

3.2.1. Use of Enterprise Service Bus for embedded Systems

SOA original comes from business IT as already mentioned. The Enterprise Service Bus (ESB) [3-2], [3-3] is a term that intents to cover a set of software tools applying distributed services. It is usually applied in specific domains. It can be seen as a specific implementation technology for SOA. It is not using DPWS. Now, some academic activity has been started to use ESB for embedded devices. This is just published by a German researcher from Applied University of Hannover [3-1]. The main statements are:

- Basis of the implementation approach of the Apache CXF enterprise service bus to an embedded java platform
- Main application fields are intended for automotive such as car to car communication or car to environment communication. For these applications the embedded systems in the cars have to provide SOA means.

Additionally, the Eclipse Foundation announces (March 23rd 2009 [3-4]) to release swordfish with Enterprise Service Bus (ESB) at the basis of Open Services Gateway Initiative (OSGi). ESB integrated open source projects such as Eclipse Equinox and Apache ServiceMix. Equinox provides the certified implementation of the OSGi-R4-Framework-Specification. It is intended to address embedded systems with this platform. Application reports of this approach are not yet found. One has to observe this activity in details.

3.2.2. SOA for testing of embedded system software

Testing tools for embedded devices is a well know software domain. There is one academic suggestion to use SOA for the interaction between embedded device and testing tool [3-5]. The main ideas are as followed:

- Increases of use of mobile embedded devices get advantages from using Service Oriented Architecture (SOA) for various applications
- Embedded system software testing should be based on SOA to overcome mobile restriction using the following approach:
    - Analyzing mobile application requirement,
    - Writing service specification,
    - Optimizing design,
    - Test service interoperability which derived from test case specification

3.2.3. A SOA-Based Embedded Systems Development Environment for Industrial Automation

To enlarge the community implementing SOA architecture in embedded devices it is necessary to provide development support. Thramboulidis at al [3-6] has suggested a specific approach for SOA based embedded system development environment for industrial automation. The main ideas are as followed:

- Features required in the development process are defined as web services and published into the public domain
- An infrastructure is required to build a web service based IDE
- Special focus is given to the device model and the means that such a modelling can significantly improve the development process.
- A prototype implementation demonstrates the applicability and usefulness of the proposed demand-led development process in the industrial automation domain.

3.2.4. SOA-lib for embedded systems

There is a software company in Boston (MA), the SOALIB Incorporated which claims to deliver high quality software based on Service Oriented Architecture (SOA). The primary focus is to deliver SOA libraries for diversified platform for SOA development. This company has announced that they are able to provide a SOA library for embedded systems with the following statement [3-7]:

Citation start

"SOA bridges the gap between Embedded Systems and the Enterprise

Embedded Systems has always been in a world of its own. If network connectivity was required, embedded engineers simply used low level socket API (a well know network base communication programming interface) to connect to servers or other devices. In most cases, these socket based applications had their own proprietary protocols which could not work with other enterprise software. Later these applications were modified to send XML protocols as well, but in most cases, the XML message format itself was proprietary.

People in the embedded systems industry are usually focused on the device programming to keep the size of the code and the resources used by the system to a minimum. Bringing SOA in embedded systems make the

device consume more resources as far as memory is concerned. But, SOALIB's SOA solution for embedded systems is very compact and fits within 1 MB code space. In most of the current Microcontrollers and Digital Signal Processors, 1 MB is a very small memory space. SOALIB's SOA API can be optimized for each embedded platform using the development tools used to develop the target system. In most cases, the size of the code may be easily optimized by using a very good C compiler.

Soalib's SOA solution for embedded systems has options for Java, C, C++ and hardware API"

Citation end

3.2.5. By the way its funny - SOA for lego robots

In Germany there are some students dealing with SOA and trying to implement related software in Lego-Robots. This shows that the SOA technology becomes more popular (http://soaharbor.blogspot.com/)

3.3. References

[3-1] Roman Roelofsen, David Bosschaert, Arne Koschel, Volker Ahlers: Services im kleinen Maßstab: SOA für eingebettete Systeme. ObjektSpektrum online Special 2007 - SOA. http://www.sigs-datacom.de/fachzeitschriften/objektspektrum/online-themenspecial/artikelansicht.html?tx_mwjournals_pi1%5Bpointer%5D=0&tx_mwjournals_pi1%5Bmode%5D=1&tx_mwjournals_pi1%5BshowUid%5D=2157

[3-2] David A. Chappell: Enterprise Service Bus. O'Reilly Media Inc. 2004. ISBN 0-596-00675-6

[3-3] www.de.wikipedia.org/wiki/Enterprise_Service_Bus

[3-4] http://microsite.computerzeitung.de/article.html?art=/articles/2009014/31888163_ha_CZ.html&page=9&ms=/service-oriented-architecture/index.html&pos=4&tpid=ee54f3c7-0de1-40f5-bb23-2cfdf022aee5&pid=ee54f3c7-0de1-40f5-bb23-2cfdf022aee5

[3-5] Myung-Hee Lee, Cheol-Jung Yoo, Ok-Bae Jang: Embedded System Software Testing Based On SOA For Mobile Service. International Journal of Advanced Science and Technology.

[3-6] K. C. Thramboulidis, G. Doukas, and G. Koumoutsos: A SOA-Based Embedded Systems Development Environment for Industrial Automation. Journal on Embedded Systems, Volume 2008, Article ID 312671, 15 pages, doi:10.1155/2008/312671

[3-7] http://www.soalib.com/index.jsp?page=embedded

3.3.1. List of conferences covering relevant topics

Acronym	Description	Contact
INCOM 09	IFAC Symposium on INFORMATION CONTROL PROBLEMS IN MANUFACTURING	Prof. Christian Diedrich (ifak), <christian.diedrich@ifak.eu>

3.3.2. Relevant product announcements or links to company statements

Company name	Product name and description	Contact
SOAlib Incorporation	SOA lib for embedded devices	See 3.2.4

3.3.3. New version of relevant specifications, RFCs, standarditation activities

On May 7, 2009, the OASIS Web Services Discovery and Web Services Devices Profile (WS-DD) Technical Committee unanimously approved a clarification of its charter to include additional deliverables. The Devices Profile for Web Services 1.1, SOAP-over-UDP 1.1, and Web Services Dynamic Discovery (WS-Discovery) 1.1 are available from the OASIS Standards page at http://www.oasis-open.org/specs.

The purpose of the Web Services Discovery and Web Services Devices Profile (WS-DD) Technical Committee is to define:

- A lightweight dynamic discovery protocol to locate web services that composes with other Web service specifications;
- A binding of SOAP to UDP (User Datagram Protocol), including message patterns, addressing requirements, and security considerations; and
- A profile of Web Services protocols consisting of a minimal set of implementation constraints to enable secure Web service messaging, discovery, description, and eventing on resource-constrained endpoints.

4. Networked control of physical systems

In the last period, we witnessed the stressed extension of the control networks into "collateral" domains, such as home automation. Again, most of the news comes from wireless networking approaches.

This especially in the R&D area, where, according to a recent (within the present time context) report of the OnWorld organization, investment in Wireless Sensor Network (WSN) research and development is growing in several sectors. Including both public and private sources, WSN R&D spending will reach $1.3 billion in 2012, up from $522 million in 2007 [4-1].

Wireless technologies are making their way into PACs, as they did some time ago into the PC domain. PACs and I/O systems are now offered with both wired and wireless Ethernet networking. The goal is to make using wireless for programmable automation controllers and I/O is as easy as it is for PCs and laptop computers [4-2].

4.1. Overview of progress discovered

WirelessHART

The adoption of wireless technology for control is slowly beginning to take place. A survey done by the HART communication foundation shows that 25% of the end users, mainly chemical and oil & gas companies; intend to use WirelessHART for both monitoring and control. Furthermore, almost 40% of the companies expect that they will adopt WirelessHART within the next three years.

WirelessHART standardization work is ongoing and the focus in 2009 is on device compliance testing. The first WirelessHART registered devices are expected in quarter four 2009.

The PNO WG12 has started its activity on integration of WirelessHART into Profinet and Profibus.

ISA 100

ISA announced in September 2009 that the ISA Standards & Practices Board (S&P) voted to approve the ISA-100.11a wireless standard "Wireless Systems for Industrial Automation: Process Control and Related Applications," thereby making it an official ISA Standard.

The IPSO Alliance

At the NetWorld show, the IPSO Alliance interoperability demonstration linked sensors globally to a business intelligence application provided by SAP which then fed results to a graphical application. The demonstrator collected sensor data in real time streamed from ten locations in Korea, Finland, Sweden, Switzerland, England, Canada, Colorado, Nevada and California.

For progress regarding networked embedded systems please also refer to chapter 1.1. There, the project initiatives CON4COORD, CHAT and WIDE.

4.2. Description of new solutions / progress and relation to SOCRADES

Emerson showcased their new solution for wireless PID control at the Emerson Exchange event in October 2009. The new PID algorithm accommodates wireless devices that do non-periodic updates (i.e. WirelessHART devices). Wireless devices are, thus, imposing a cross layer design approach where the control algorithm takes into account the transport media.

Nivis continued the efforts focused on ISA 100 developments, and provides "the world's first ISA100.11a Integration Kit."

4.3. References

[4-1] OnWorld. Wireless Sensor Networks - R&D Trends and Funding Opportunities. Jan. 2009. http://www.onworld.com/wsntrends/index.html.

[4-2] PAC Project 8.5. Opto22, www.opto22.com.

4.3.1. List of conferences covering relevant topics

Acronym	Description	Contact
EFTA2009	IEEE conference on emerging technologies and factory automation	
Exchange	Emerson Exchange 2009	

4.3.2. Relevant product announcements or links to company statements

Company name	Product name and description	Contact
Nivis	ISA100.11a Integration Kit "The ISA100.11a Integration Kit will act as a complete end-to-end system which includes backbone router, gateway, System Manager and Security Manager processes. The system will	http://www.nivis.com/Home/default.aspx

	provide wireless monitoring and control over industrial and commercial applications with a standards-based, highly reliable network. The Nivis system architecture supports ISA100.11a, WirelessHART or both protocol stacks simultaneously."	
Opto22	PAC Project 8.5: supports all components in the recently released Wired+Wireless family, which adds wireless LAN (Wi-Fi) capabilities to the vendor's Ethernet-based SNAP I/O processors and SNAP PAC standalone and rack-mounted programmable automation controllers.	www.opto22.com

4.3.3. New version of relevant specifications, RFCs, standardization activities

Reference	Document Title and URL	Revision
	First ISA Industrial Wireless Standard Approved	

4.3.4. Relevant projects

Acronym	Title	Status and results	Contact
CON4COORD	Control for coordination of distributed systems	Start: May 2008 Duration: 36 months INFSO-ICT-223844	Stichting Centrum voor Wiskunde en Informatica, Amsterdam Jan .H. Van Schuppen Tel.: +31-20-5924085
WIDE	Decentralised and wireless control of large scale systems	Start: Sept 2008 Duration: 36 months INFSO-ICT-224168	Univ. Degli Studi di Siena, Italy Alberto Bemporad Tel.: +39-057-723463
CHAT	Control of heterogeneous systems: technologies for scalability, reconfigurability and security	Start: Sept 2008 Duration: 36 months INFSO-ICT-224428	Univ. di Pisa, Italy Antonio Bicchi Tel.: +39-050-221705

4.3.5. Network activities

Acronym	Subjects covered	Status and results	Contact
Objective ICT-2009.3.5	• Foundations of complex systems	Open Call	EU Embedded

Acronym	Subjects covered	Status and results	Contact
Engineering of Networked Monitoring and Control systems	engineering • Wireless Sensor Networks and Cooperating Objects • Control of large-scale systems		Systems

5. Wireless technologies, candidates for automation

5.1. Overview of progress discovered

Wireless Sensor Networks in the Process Automation Domain

The requirements of wireless appliances dedicated to the domain of Process Automation differ from requirements of wireless sensors in the domain of Factory Automation.

Overview of the requirements of WSN in Process Automation:

- high reliability
- long lifetime and long mean time between maintenances
- long battery life (> 5 years)
- relatively large number of devices in the network that monitor and control the process automation
- moderate performance
- latency: hundreds of milliseconds to minutes
- throughput: 100 bps to ten's of Kbps
- coverage: relatively large area (e.g., 2km x 1km)
- ease of use

A communication standard is necessary to create products which are successful in the market. The customers of the process automation domain have driven standardization activities within the HCF (HART Communication Foundation). The resulting WirelessHART specification (W-HART) has been released in 2007. This standard is based on the communication standard IEEE 802.15.4. W-HART is part of the HART 7 specification. It perfectly fits the given requirements and is broadly accepted in the world of process automation in the mean time.

Wireless Sensor Networks in the Factory Automation Domain

The requirements of the Factory Automation Domain are not so "relaxed" compared to the requirements of Process Automation Domain.

Overview of the requirements of WSN in Factory Automation:

- high reliability, high determinism
- very low latency:
  - transmission of sensor data in ≤ 10 ms
  - short duration between subsequent transmissions
- very small data
  - data might be only 1 byte
- many sensors per gateway (up to 250)
- different traffic patterns
- limited traffic:
  - sensors send data only infrequently
  - often event-triggered

- heavy traffic:
  - sensors send data (very) frequently
  - often continuous data transmission
- star topology
- short header (minimal overhead in data frames)
- flexible superframe structure
- roaming between gateways

The PNO, ISA SP100 and TG4e within the IEEE 802.15 are all active to generate standards to be used in this domain.

The PNO members have decided to bring the ABB approach "WiSA" to standardization for WSN in the Factory Automation Domain. Some of the PNO members support this activity, the other are searching for a different communication standard as a basis. Currently, there is no general consensus among the PNO members.

The ISA SP100 activities are pretty broad because the community wants to cover the process and factory automation domain with one common standard for WSN. This standard should also include security and even the energy supply of the sensor. The ideas are very promising. However, it is hard to estimate when the results will emerge because of the huge number of considered subjects and different requirements of different domains.

The TG4e activities within IEEE 802.15, which are elaborated in the next section, are not emerging in the near future, either. The goal is to improve the MAC layer related to a slotted operation mode. In contrast to the W-HART standard, it is pretty incomplete, because W-HART defines everything up to the application layer (interoperable from customer point of view) and 802.15.4e defines only up to the top edge of the MAC. Thus, after IEEE 802.15.4e has finished its work, some other institution would have to come up with a standard on top of it, in the same way as W-HART is built upon IEEE 802.15.4. It is not very likely this will happen anytime soon.

Conclusion: There are a couple of activities of standardization but no standard to be seen.

5.2. Description of new solutions / progress and relation to SOCRADES

Standardization Activities in the IEEE 802.15.4

The non-profit organization IEEE has described and standardized the physical (PHY) and medium access (MAC) layer for WPAN within the IEEE 802.15.4. The IEEE 802.15 TG4 was chartered to investigate a low data rate solution with multi-month to multi-year battery life and very low complexity. It is operating in an unlicensed, international frequency band (ISM band). Potential applications are sensors, interactive toys, smart badges, remote controls, and home automation.

To improve PHY and MAC, several working groups have been established under the name TG4x. The task group 4e (TG4e) is about to improve/optimize/enhance the properties of the MAC of the 802.15.4 standard, matched to the requirements of application domains, such as factory automation, process automation, asset tracking, general sensor control (industrial/commercial, including building automation), home medical health/monitor, and neighborhood area networks.

Siemens AG is an active member in the TG4e. In this task groups, there are two proposals. Mitsubishi supports a proposal of Siemens for an improved 802.15.4 communication stack, potentially suited for the factory automation domain. The main focus is to have short cycle times, short latency time, TDMA behavior (slotted communication), and real time behavior.

A second proposal of the companies Dust Networks, Freescale, Emerson, and Siemens aims at the definition of a "Time Slotted, Channel Hopping MAC" which can be applied in equipment and process monitoring, non-critical control, diagnostics/predictive maintenance, and asset management.

This work is ongoing.

"IP to the Field" - IPSO, ROLL, 6LoWPAN

Backed up with large support from manufacturers and IT companies, the IPSO (http://www.ipso-alliance.org) and the IP500 (http://ip500.org) Alliance promote the idea of end-to-end IP connectivity down to the field device level. Advantages of the integration of the IP layer into a sensor node stack are simplifications in the design and configuration of gateways, as only the physical and data link layers have to be translated. In addition, existing protocols and tools to manage and diagnose the network can be reused, which reduces the cost of operating (OPEX) a system.

From a technical perspective the protocols for the "IP to the Field" technology are developed in the IETF working Groups "IPv6 over Low power WPAN" (6LoWPAN) and "Routing Over Low power and Lossy networks" (ROLL).

6LoWPAN defines the transmission of IPv6 packets over 802.15.4 networks and therefore builds the foundation for the wireless integration of field devices in IP networks. The working group has already defined the packet format in RFC 4944. Current work focuses on header compression and neighbor discovery mechanisms.

The working group ROLL aims at defining a mesh routing protocol suitable for the integration of field devices in IP networks. After collecting the requirements of several application areas (industrial, home automation, building automation, urban networks) and reviewing existing routing protocols, the group published a first draft of the ROLL routing protocol in August 2009. The protocol is designed for low resource usage and optimizes multipoint-to-point and point-to-multipoint communications. An interface to the lower protocol stack layers, which provides access guarantees is still under discussion.

ZigBee Green Power

More than 230 companies are active in the ZigBee Alliance. The overall goal is to achieve interoperability of wireless devices or appliances based on IEEE 802.15.4. The alliance has identified the power supply to be a barrier preventing a broad deployment of wireless appliances. The ZigBee Alliance addresses this problem with the future specification extension "ZigBee Green Power". This specification will describe new functionality for the extension of ZigBee networks. It includes new possibilities of power generation, like energy harvesting to eliminate the usage of chemical batteries. The goal is to have a standard, which allows for maintenance-free, eco-friendly wireless devices which don't require any kind of cable.

The new standard shall be available by the end of 2009.

Bluetooth based on WLAN

Nowadays Bluetooth is mostly used in cell phones, smart phones and notebooks. In most cases, Bluetooth is used for short distances and low to medium data rates. Nevertheless, the need for higher data rates is steadily increasing. At the end of April 2009, the Bluetooth Special Interesting Group (SIG) has launched a new specification, called "Bluetooth 3.0+HS". The goal is to be able to transmit big data files in the megabyte range between portable devices. In this new Bluetooth specification, a high-speed communication channel is

used. The SIG envisioned WLAN and UWB as candidates for this high-speed channel. However, the current specification only adds WLAN, while UWB is completely missing from it.

In order to add additional channels, the new Bluetooth specification 3.0+HS has decoupled the higher levels of the communication stack from the PHY/MAC IEEE 802.15.1. The higher protocol levels of Bluetooth can be combined with different physical, medium access and transport layers with the help of this abstraction, the so-called "Alternate PHY/MAC Manager" (AMP).

This change in the Bluetooth architecture could have impact to the industrial domain, as WLAN has an already installed basis there. This trend might be interesting for the manufacturers or the process industry community for applications with wireless portable devices.

ISA SP100

The intended standard ISA 100 Wireless Systems for Automation aims at one wireless structure for industrial use, incorporating multiple industrial communication protocols. 600 members are participating representing more than 200 companies, with more than 65 voting members. Participation is organized in working groups (WG):

- WG1: ISA100.1, Integration. Ties the standard together. Technical Report "ISA-TR100.00.01-2006 - the Automation Engineer's Guide to Wireless Technology Part 1: The Physics of Radio, a Tutorial".
- WG2: Technical RFP Evaluation Criteria (TREC). Development of wireless requirements. This group is not active at this point, as ISA100.11a has embraced all stated requirements to date.
- WG3: ISA100.11a, Wireless for Process Monitoring. Focuses on wireless sensor technology in industrial environments with 100 ms latency or longer and non-critical or risk-acceptable applications. Draft 2 was approved and balloted for ANSI public review. Final version was submitted to ANSI standards and practises board in September 2009. Some member companies have already produced products and prototypes according to ISA100.11a, which are claimed to be compliant or will be after minor firmware adjustments.
- WG8: User requirements, including battery lifetime, will be addressed.
- WG12: ISA100.12, WirelessHART Convergence. Currently, dual boot devices are considered where two stacks are implemented together, in order to let WirelessHART and ISA100.11a work together. It is not decided yet if the devices should be able to handle both stacks, or if they have to be reprogrammed in order to change the stack. Any way, the current discussion does not favour a solution that would allow operating both stacks simultaneously.
  The dual-boot approach would allow HART to keep its intellectual property. The group is working on an objective document comparing each. One difference is that WirelessHART requires every single wireless device to be able to act as a router, while ISA100.11a allows for wireless devices that can act as routers, but also for wireless devices that cannot.
- WG15: Wireless Backbone/Backhaul. Aims at substituting wired Ethernet to the control room.
- WG16: Factory Automation. Will produce a normative standard for wireless factory automation, e.g. with tighter timing than ISA100.11a. A requirements document is being drafted.
- WG21: People and Asset Tracking. Covers RFID and other methods. This group has produced a related technical report.

5.3. References

[5-1] Hoske, Wireless Standards, Control Engineering July 2009, p.35

5.3.1. List of conferences covering relevant topics

Acronym	Description	Contact
ETFA2009	14th IEEE International Conference on Emerging Techonologies and Factory Automation	

5.3.2. Relevant product announcements or links to company statements

Wireless Sensor Networks in the Process Automation Domain

First W-HART stack implementations are visible on the market. These solutions offer boxed hardware and a programming interface for the specific application (customer API). This is a starting point for a production deployment, but it is not satisfying for every customer.

Therefore a group of key suppliers of the process automation domain have founded the so-called "Wireless Industrial Technology Konsortium" (WiTECK) consortium. WiTECK has the goal to develop core software for approved standards. They want to provide system software for industrial wireless sensing applications which are reliable, cost-effective, platform-neutral, and interoperable. The first project is to develop a W-HART stack to become a 2nd source. The consortium members will get a license for using the source code at no additional cost. Non-members will be able to buy the license. In a following step, it is planned to improve or otherwise enrich the stack.

6. Device profiles of devices connected to industrial communication networks

6.1. Overview of progress discovered

In October 2008 PLCopen and OPCFoundation have started common activities to jointly define a common information model (http://www.plcopen.org/pages/whats_new/tc4/opc_ua.htm). There are information models under development for Electronic Device Description (EDD) and now also for IEC 61131 PLC. This is important because field devices which are described in EDD and in future which are represented by PLC proxies can be accessed by OPC UA web services. In connection with the SOCRADES approach for OPC UA/DPWS translators, field device profile information are part of the SOA architecture.

6.2. Description of new solutions / progress and relation to SOCRADES

There is nothing additional new in the fieldbus profile domain.

6.3. References

[6-1] PLCopen and OPC UA activity described above is not yet published in papers because the technical work is not finalised.

[6-2] Mahnke W, Leitner S-H and Damm M, OPC Unified Architecture, Springer, ISBN 978-3-540-68898-3, 2009

7. Engineering of distributed systems

The distributed systems domain is continually changing. The changes are mainly driven by customer and market demands, and more recently by the global economical turmoil. More noticeably in the recent months is a trend towards partnerships between main service providers in this industry to support a wider scope of product life cycle. To align with this trend, it is envisaged that the SOCRADES project should continue to

support the integration vertically (high level management to low level device) and horizontally (wider scope of product life cycle).

7.1. Overview of progress discovered

In August 2009, the strategic partnership of Dassault Systèmes and Rockwell Automation that combines the ELMIA Automation Platform with the RSLogix 5000control design and programming environment delivers a new and more robust environment merging virtual simulation and automation for production. The combination of these two technologies will allow concurrent development of mechanical, electrical, and control systems for production lines, automated assembly, and work cells. This environment, called Virtual Design & Production, goes beyond Digital Manufacturing and claims that it will virtually eliminate errors between the integration of mechanical and electrical production systems significantly reducing the time and cost for production system commissioning and dramatically shorten the time to product launch. Furthermore, early this year, the Dassault Group has released their new development and collaborative platform (V6) on top of which their Virtual Manufacturing and PLM Tools are built. The platform provides an improved integration between the different software modules and collaboration tool (i.e. the PPR communication Hub, ENOVIA online collaboration tools). Part of the improvement of the V6 platform in the domain of distributed engineering and collaborative capabilities has been achieved through the Collaboration with the Intercim Group that is specialized in the development of distributed manufacturing and production operations management. Intercim provide Dassault through their Pertinence Suite, (based on Microsoft® .NET architecture, a thin client, web-based solution that uses portal technology, i.e. Advanced Integration Services (AIS) layer designed on top of a service-oriented architecture (SOA) to allow maximum flexibility and interoperability within and outside the enterprise.

Another example of trend towards supporting wider product life support was exhibited by Siemens in EMO Milano 2009, where a combination of its PLM software and production systems and equipment was displayed. Siemens announced the adoption of Teamcenter as its corporate-wide standard for Siemens automation division to support product life cycle management. The Siemens PLM also released the Teamcenter Express (V5) that adds a set of new productivity improvements to cPDm solution for SMBs. The new release has integrated Microsoft Office™ and the new cost analysis tools for both products and projects.

Rockwell Automation has recently announced major collaboration program with seven automation service providers to support a broader market experience and greater technological expertise of control and automation solutions. This program is aimed at helping its members increase market awareness with end users, expand into new market sectors, and improve technical and functional excellence. The participating service providers include: Custom Control Manufacturing (provides PLC and HMI programming services), E-Technologies Group (executes all phases and aspects of automation projects), Grantek (provides integrated automation services), JNE Automation (provides engineering services ranging from machine design to on-site startup), Melfi Technologies (process automation), Power Engineers (designs and commissions integrated control and information management systems), the Stellar Group (design, engineering, construction, mechanical).

7.2. Description of new solutions / progress and relation to SOCRADES

The current trend in distributed systems and virtual engineering tools seems to emphasis on the collaborative capabilities. Major actors in VE (i.e. Delmia Dassault and Unigraphics) have built complex VE solutions based on the tight integration between large DMS and 3D-based software modules. However, the benefits of deploying such large and costly solutions was often and is still limited by the fact that information could not be shared effectively in scenarios where distributed partners with different software solution and IT infrastructure. VE solutions providers are now looking in increasing the collaborative

capabilities by enabling data sharing and remote access through opened network infrastructures, hence enabling real time online creation, collaboration and concurrent engineering.

In this regard, it is important that SOCRADES maintains its emphasis on multi dimensional integration approach, and its comprehensive engineering application services.

7.2.1. List of conferences covering relevant topics

Acronym	Description	Contact
ISDM	The 2nd International Symposium on Digital Manufacturing (ISDM 2009)	10-11th September 2009, Wuhan, China
CFP	Sixth International Conference on Remote Engineering and Virtual Instrumentation (REV 2009)	22 Jun 2009 - 25 Jun 2009, US
EMO Milano	The machine tool world exhibition	5-10 October 2009
ETFA 2009	14th IEEE Int. Conf. on Emerging Technologies and Factory Automation	Sept 09
SIAR	Computational Mechanics and Virtual Engineering with Applications in Automotive Engineering	29-30 October

7.2.2. Relevant publications

[7-1] R.Harrison, R.P.Monfared, L.Lee, Business Driven Engineering for Powertrain Industry, 14th IEEE Int.Conf. on Emerging Technologies and Factory Automation - ETFA 2009, Spain

[7-2] Y.S.Park, T.Kirkham, P.Phaithoonbuathong, R.Harrison, Implementing Agile and Collaborative Automation using Web Service Orchestration, , ISIE 2009 - IEEE International Symposium on Industrial Electronics – July 2009, Seoul

[7-3] P. Phaithoonbuathong, T. Kirkham, R. Harrison, R. Monfared and A. West,Web Services- based Automation for the Control and Monitoring of Production Systems, IJCIM, July 2009

7.2.3. Relevant product announcements or links to company statements

Company name	Product name and description	Contact
Rockwell Automation	Collaboration with engineering service providers http://www.rockwellautomation.com/	
Siemens	PLM/Teamcenter product announcement http://www.plm.automation.siemens.com/en_us/	
Delmia/ Rockwell	Partnership in developing the new Digital Factory product http://www.managingautomation.com/	

8. Business process integration of networked devices related data

There were no other new activities, which have not already been reported in the last trend screening reports.