EUROPEAN COMMISSION

Thematic Priority:
SIXTH FRAMEWORK PROGRAM

Priority 2.5.3
INFORMATION SOCIETY TECHNOLOGIES
Unit G3 Embedded Systems

Project Acronym:

SOCRADES

Project Full Title:

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

Proposal/Contract No: EU FP6 IST-5-034116 IP SOCRADES

Deliverable D1.3
Trend screening report 1

Status:	**Final**
Dissemination Level:	**CONFIDENTIAL**
Date:	**14.01.2008**

Organization Name of the Lead Contractor for this Deliverable: **ifak**

Status Description:

Scheduled completion date:	30.11.2007	Actual completion date:	14.01.2008
Short document description:	Based on the initial state-of-the-art analysis, done in D1.1, this document describes the progress in state-of-the-art discovered till month 15 of the project duration. The final version of D1.1 has been submitted at the end of month 13.		

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Contributions	Peer reviews	Partner
X	X	Schneider Electric
X	X	ABB
X		APS GmbH
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	X	Luleå University of Technology
X		Politecnico di Milano
X	X	SAP AG
X		Siemens AG
X		Tampere University of Technology
		Jaguar Cars Ltd.
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Peer review approval :	[X] Approved [ ] Rejected (improve as specified hereunder)	Date:	14.01.2008
Suggested improvements:	No improvements		

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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, 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 will be 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. Here strong activities related to OPC UA have been noticed recently. 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 D1.3 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

1.1. Overview of progress discovered

Complex control systems require the integration of customer-bound functionality and control algorithms with a variety of different components, technologies and resources. Although many of the components are supported by different types of hardware platforms and operation systems, in the end they all have to interact with each other towards a common goal.

To enable such systems to operate robust and reliable is - from the control engineering point of view - a challenging process and requires always specifically tailored engineering efforts for each installation.

This is especially obvious in terms of the configuration and integration of components and devices. This has to be as flexible as possible aiming to allow rapid reconfiguration as well as fast adaptation to react to environmental or process-related changes by means of sensors and real-time processing of sensor data input.

To meet these goals, typically controller elements are not centralised. They are distributed throughout the system with each component subsystem controlled by one or more control units acting as scalable computational resources. For communication and monitoring purposes the controllers are connected by a network.

The term "distributed control systems (DCS)" is used while applying controllers for control and monitoring of distributed equipment. DCSs are connected to sensors and actuators. They typically use set point control to guide the flow of processes, material and work through the plant.

In this context input and output modules are essential parts of a DCS. They can be integral with the controller or located remotely via a field network while communication is typically performed by using both proprietary interconnections as well as standardized protocols.

Starting with the network-centric era of the 1980s the DCS technology brought intelligence into the plants. TCP-IP was developed to increase openness and Ethernet-based networks were adopted to support global data access and management. The development of micro processors and microcontrollers provided the platforms for the next generations of DCS for manufacturing and process control. The first PLCs were integrated into the DCS infra-structure.

Then, in the 1990s very soon the DCS suppliers introduced a new generation of DCS technology based on latest communication and IEC standards following a trend of combining traditional concepts and functionality of PLC and DCS into a one for all solution. It is known as "Process Automation System / Controller".

In line with this evolution of DCS technology we see a transition from the pure control hardware business to one based on software and value-added services.

Today in accordance to the O3neida network which is fostering distributed industrial automation based on open standards [1], the automation industry can be characterised by a highly proprietary environment. Different platforms and tools are normally in use. But there is in many cases no interoperability between different solutions of different vendors [2].

Although the standard IEC 61131-3, which deals with programming languages standards for PLCs provides a basis for common modelling of control software, many of the platforms and tools utilised are not able to interoperate.

Therefore PLCopen as a product independent worldwide operating association to extend and support automation control programming standards has started initiatives to improve this situation [3]. Especially in the field of PLC programming standards PLCopen was very successful in the past. Now their focus is to improve the motion control standards also.

As hardware meanwhile constitutes less the price of automation systems, today the costs of creating user software becomes of emerging importance. Software for complex DCS installations is estimated to produce costs in average of more than 50% of the total cost of an automation project. Therefore engineering is a key factor to reduce costs [4].

Many automation system suppliers favour unique engineering tools, consisting of automation functions and the operator interface to configure the entire system including field bus configuration and parameterization of field devices. Graphical configuration with high performance editors in programming languages according to IEC 61131-3 in combination with an extensive function block library, to which user-defined function blocks can be added for fast reconfiguration, is commonly used. [4].

In order to overcome the deficits of proprietary control solutions and to extend IEC 61131-3 functionality, the IEC 61499 was born to standardise the interoperation of heterogeneous components in distributed control systems. Core element of the IEC standard 61499 are functional blocks which consist of encapsulated data and algorithms to perform a certain task. Each functional block is accessible from a library and can be used on demand with other functional blocks to generate executable automation control programmes with DCS technology.

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

In the context of IEC 61499 the 4DIAC project [2] mentioned above has started in July 2007 to provide an IEC 61499-compliant basis that gives the opportunity to establish an automation and control environment which will be based on the three key targets: (i) portability, (ii) configurability and (iii) interoperability.

This means in detail:

- Provision of a common basis for development, industrial appliance and research of IEC 61499;
- Provision of a package containing a runtime environment for different embedded control platforms and the corresponding engineering environment,
- Provision of real-world examples at prototype level.

For the runtime environment it is planned to develop first a small portable implementation of IEC 61499 targeting small embedded control devices. The platform provides the execution of basic function blocks, composite function blocks and service interface function blocks.

In parallel the 4DIAC project intends to provide an extensible engineering environment for modelling control applications with IEC 61499. A hardware capability definition based on FDCML allows the modelling of control hardware and its interconnections through networks. The modelled applications can be downloaded to and uploaded from the device according to the IEC 61499 standard. Basis is the Eclipse framework. It allows an easy plug-in of modules related to new and extended functionality. 4DIAC activities are based on the eCEDAC project (Evolution Control Environment for Distributed Automation Components) [5] which aims on downtimeless reconfiguration of components in distributed automation and control systems by means of existing control modelling languages like SIMULINK or IEC 61499.

To support reconfigurability, scalability and distribution into functional modules at low-level controls and even at real time conditions in DCS, the research project μCrons focused its activities on the development of so called “Micro –Holons” which are online-reconfigurable real-time controlled mechatronic basic building blocks for the next generation of agile DCS applications [6]. The vision of the μCrons project is to enable the use of completely new , active, reconfigurable embedded automation components that allow to compose and change automation systems out of “Plug & Work” components also during full operation and with “zero downtime”. Key standard as foundation for the development is again IEC 61499. In the context of function blocks for advanced control applications, μCrons has extended IEC 61499 by functions to support realtime processes and reconfiguration services. The reconfiguration services explicitly enable online modification of control software in networks with heterogeneous controller elements.

To summarize the trend screening activities in the field of DCS it is to point out that the IEC 61499 standard is able to create a promising platform for the next generation of distributed automation and control systems. Today, industrial networking software providers have already started to build network control and monitoring applications that take the function block approach of IEC 61499 to defining industrial networks comprising disparate field bus components that traditionally could not communicate.

With IEC 61499 a standard is available which provides the higher level (yet executable!) abstraction appropriate for model-based engineering of distributed embedded systems.

1.3. References

[1] O3neida: Network of Networks to advance Distributed Industrial Automation, 2007, http://www.oooneida.info/index.html

[2] 4DIAC – Framework for Distributed Industrial Automation and Control, 2007

http://www.fordiac.org

http://www.oooneida.info/RD_projects_ODC_Environment.html

[3] PLCopen- for efficiency in automation, 2007. http://plcopen.org/

[4] ABB Freelance 800F , 2007 http://search.abb.com/library/ABBLibrary.asp?DocumentID=3BDD010023&LanguageCode=en&DocumentPartID=&Action=Launch

[5] eCEDAC – Evolution Control Environment for Distributed Automation Components, 2005-2007, http://www.easydac.org/

[6] µCrons – MicroHolons for Next Generation Distributed Embedded Automation and Control, 2004-2007, http://www.microns.org/

2. Agent-based control

2.1. Overview of progress discovered

The overview that is given about the progress discovered in the topic among agent-based control since the release of deliverable D1.1 is focused on a list of publications or published project reports, particularly of the FP6 project PABADIS´PROMISE.

Building on top of the successful FP5 Project PABADIS, the PABADIS'PROMISE project extends the idea of distributed control to an architecture, which incorporates both resource and product, emphasized by the project's new paradigm "The Order is the Application". Moreover, the project's vision considers the integration of new technologies such as RFID into products, plug-and-play of manufacturing capabilities and mobile agents (agent on RFID).

2.2. References

2.2.1. Relevant publications

- J. Lastra, C. Insaurralde and A. Colombo, chapter: "Agent-based Control for Desktop Assembly Factories", Smart Devices and Machines for Advanced Manufacturing, Springer Verlag, 2007
- K. Feldmann, M. Weber and W. Wolf, "Design of a theoretical holistic system model as base of construction kits for building Plug&Produceable modular production systems", Production Engineering Journal, vol. 1, num. 3, pp 329-336, 2007

2.2.2. Relevant projects

Acronym	Title	Status and results	Contact
PABADIS´PROMISE	PABADIS based Product Oriented Manufacturing Systems for Re-Configurable Enterprises		http://www.pabadis-promise.org

3. Service-Oriented Architectures for Devices

Although there is not a clear specialization of the Service-Oriented Architectures for automation related architectures, several approaches were presented in D.1.1. Technologies such as Universal Plug and Play (UPnP), Devices Profile for Web Services (DPWS), OPC/OPC UA have extended their original application to the automation field. Particularly DPWS has an important role in the implementation of SOA in devices.

3.1. Overview of progress discovered

The emergence of the DPWS supposed a similar technological advantage such as the UPnP devices. DPWS evolution is tracked by the large number of vendors and product manufacturers interested on its development and practical application.

The common interest makes possible the advance on DPWS based technologies. There are commercial solutions such as the one developed by Best Buy and Hewlett Packard to create solutions for home automation.

Although the co-existence of the aforementioned commercial solutions, there are other initiatives which provide open source solutions that can be exported into different areas, such as SOA4D Forge. This initiative aims to develop a supporting environment where the developers of Service-Oriented Architecture for Devices can find new solutions and implementations.

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

The new solutions provided under the SOA4D Forge, such as WS-management module for DPWS, can be exported in a near future into SOCRADES. The active involvement of some SOCRADES partners in the initiative will provide a valuable advantage at the moment of implementing practical solutions.

3.3. References

3.3.1. List of conferences covering relevant topics

Acronym	Description
CMMSE	International Workshop on Context Modelling and Management for Smart Environments (CMMSE)
AINAW	21st International Conference on Advanced Information Networking and Applications Workshops

3.3.2. Relevant publications

- N. Bussière, D. Cheung-Foo-Wo, V. Hourdin, S. Lavirotte, M. Riveill, J.Y. Tigli, "Optimized Contextual Discovery of Web Services for Devices", Proceedings of the International Workshop on Context Modelling and Management for Smart Environments (CMMSE), IEEE, Lyon, France, 28-31, October 2007.

- D. Barasic, M. Krogmann, G. Stromberg and P. Schramm,"Making Embedded Software Development more Efficient with SOA", 21st International Conference on Advanced Information Networking and Applications Workshops 2007 (AINAW'07), 2007.

3.3.3. Relevant product announcements or links to company statements

Company name	Product name and description	Contact
LifeWare	Digital Entertainment and Automation http://www.exceptionalinnovation.com/	See link
	New software merges devices and technology http://www.tmcnet.com/usubmit/2007/01/10/2236811.htm	See link

3.3.4. New version of relevant specifications, RFCs, standardisation activities

Reference	Document Title and URL	Revision
DPWS	Devices Profile for Web Services http://schemas.xmlsoap.org/ws/2006/02/devprof/	May 2005
DPWS	DPWS Management Requirements http://www.soda-itea.org/Documents/Specifications/1180017984.75.html	May 2007

4. Networked control of physical systems

Some progress has been achieved in the topic of Networked control. New PID tuning rules applicable to the networked setting have been developed. This progress will be described in the following sub-section. On the other hand, there has also been some progress in decentralized optimization and networked estimation and tracking. We will not describe these in detail but information on these advances can be gathered from the references at the end of this section.

4.1. Overview of progress discovered

Networked PID tuning rules: There has been some progress in the design of PID controllers for systems with varying time-delays. The motivation for varying time-delays comes from the fluctuations in packet delivery times on Networks. Using the concept of Jitter margin combined with the AMIGO tuning rule methodology, novel tuning rules that are robust to varying time-delays are derived. In addition, we give an expression for the expected lower bound of the jitter margin as these tuning rules are applied. Extensive numerical evaluations demonstrate that, for wide range of processes, the new tuning rules achieve significant improvements in jitter margin at the expense of only slight decreases in other performance criteria.

ISA100.

ISA100.11a Working Group Scope: This project will define all specifications including security and management; for wireless devices serving application classes 1 through 5 for fixed, portable and moving devices.

The project's application focus will address performance needs for periodic monitoring and process control where latencies on the order of 100 ms can be tolerated with optional behaviour for shorter latency.

4.1.1. List of conferences covering relevant topics

Acronym	Description	Contact
CDC 07	Conference on Decision and Control, December 2007	http://iss.bu.edu/dac/dac/cdc/index.php
ACC 07	American Control Conference, July 2007	http://www.a2c2.org/conferences/acc2007/
ECC 07	European Control Conference, July 2007	http://ecc07.ntua.gr/

4.1.2. Relevant publications

- L. M. Eriksson, M. Johansson, "PID Controller Tuning Rules for Varying Time-Delay Systems", Proceedings of the American Control Conference, July 2007.
- B. Johansson, M. Rabi, M. Johansson, "A Simple Peer-to-Peer Algorithm for Distributed Optimization in Sensor Networks", Proceedings IEEE Conference on Decision and Control, December 2007.
- L. Shi, K. H. Johansson, R. Murray, "Change Sensor Topology When Needed: How to Efficiently Use System Resources in Control and Estimation Over Wireless Networks", Proceedings IEEE Conference on Decision and Control, December 2007.
- Jim Montague. Survey Snapshots Wireless Users. ControlGlobal.com, http://www.controlglobal.com/articles/2007/244.html. August 2007.
- Why Wireless Hart? The Right Standard at the Right Time. http://www.hartcomm2.org/hart_protocol/applications/white_papers/why_wirelesshart.html. Oct. 2007.

4.1.3. Relevant product announcements or links to company statements

Company name	Product name and description	Contact
Emerson	Ovation® SCADA Solution for Wind Energy Management	http://www.emersonprocess-powerwater.com/news/pr/Ovation_SCADA_forWind.htm

4.1.4. Relevant projects

Acronym	Title	Status and results	Contact
WiSA	The main objectives of the project are the development of ▪ wireless communications (MAC and network layers) ▪ distributed data fusion algorithms • sensor, network and process diagnostics • distributed and hierarchical control principles.	Duration: 2005 –2010.	http://www.control.hut.fi/Research/wisa/
RUNES	The RUNES project has a vision to enable the creation of large-scale, widely distributed,	Duration: Sept 2004 –	http://www.ist-runes.org/introductio

Acronym	Title	Status and results	Contact
	heterogeneous networked embedded systems that interoperate and adapt to their environments.	May. 2008.	n.html

4.1.5. Network activities

Acronym	Subjects covered	Status and results	Contact
HYCON	Networked embedded systems design: analysis, modelling, simulation, synthesis, communications and advanced control.	Duration: Sept 2004 – Aug. 2008.	http://www.ist-hycon.org/index.php?p=Home
Artist2	Embedded systems are deployed in the real world, and are often reactive to it. This interaction with the environment is intrinsic to the service provided. A large proportion of embedded systems can be considered to be controllers. On the other hand, most automated control applications will be implemented as embedded components. Thus, it is essential that work on joining control theory and embedded systems be included in the ARTIST2 NoE. The focus of the research in the Control for Embedded Systems cluster is implementation-related real-time issues for networked embedded control systems and control of real-time computing and communications systems.	Duration: Sept 2004 – Aug. 2008.	http://www.artist-embedded.org/artist/-Home-Page-.html

5. Wireless technologies, candidates for automation

5.1. Overview of progress discovered

The Gartner Group's Hype Cycle for Wireless Networking shows the mainstream adoption of different wireless technologies in the future (**Figure 1**):

- Wi-Fi 802.11 a/b/g and Bluetooth Version 2.0 are on the "Plateau of Productivity". Concerning IEEE 802.11 this is also true for the industrial wireless networking market. According to a recently completed study by the Venture Development Corporation (VDC) IEEE 802.11 "is the de facto market leader" [23].
- Mesh Networking is on the way to leave the "Trough of Disillusionment" and comes to the "Slope of Enlightenment". Mainstream adoption is expected in the following 2 to 5 years.
- The Gartner Group sees IEEE 802.11n still at the "Peak of Inflated Expectations". This fits to statements in the technical press like "IEEE 802.11n will change the WLAN market considerably" [14]. The CIBC World Markets Corporation also holds that the market will shift rapidly to IEEE 802.11n and will dominate in 2009 (**Figure 3**).
- The mainstream adoption of Mesh Sensor Networks will take more than ten years.

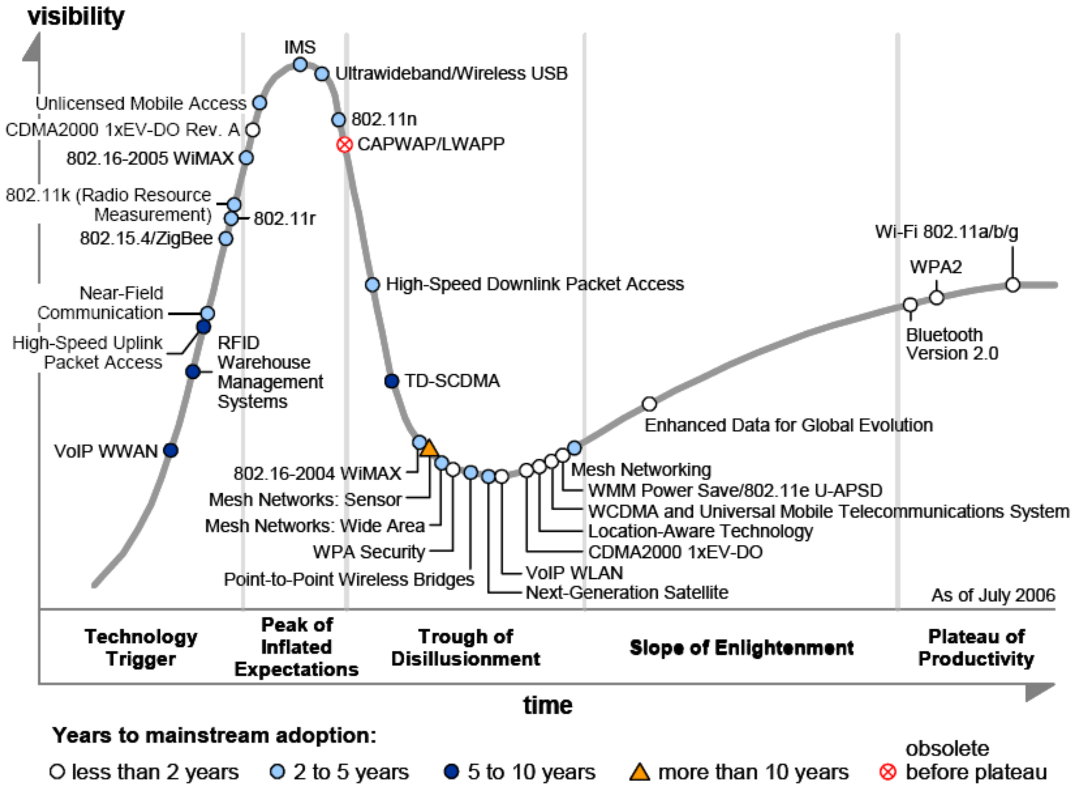

Figure 1: Hype Cycle for Wireless Networking, 2006 [21]

The Gartner Group expects the highest benefit from Mesh Networking and Wireless Sensor Networks (see table below, Priority Matrix for Wireless Networking, 2006 [21]. In contrast to the high expectations the Gartner Group sees only a moderate benefit in the application of IEEE 802.11n. Mainstream adoption of Bluetooth Version 2.0 will take less than two years but the benefit is expected to be low.

benefit	years to mainstream adoption			
	less than 2 years	2 to 5 years	5 to 10 years	more than 10 years
transformational		Near-Field Communication Ultrawideband/Wireless USB	VoIP WWAN	
high	CDMA2000 1xEV-DO Location-Aware Technology WMM-Power Save/802.11e U-APSD WPA2	802.15.4/ZigBee High-Speed Downlink Packet Access Mesh Networking	High-Speed Uplink Packet Access RFID Warehouse Management Systems	Mesh Networks: Sensor
moderate	CDMA2000 1xEV-DO Rev. A Enhanced Data for Global Evolution VoIP WLAN WCDMA and Universal Mobile Telecommunications System Wi-Fi 802.11a/b/g	802.11k (Radio Resource Measurement) 802.11n 802.11r 802.16-2004 WiMAX 802.16-2005 WiMAX IMS Mesh Networks: Wide Area Point-to-Point Wireless Bridges Unlicensed Mobile Access		
low	Bluetooth Version 2.0 WPA Security	Next-Generation Satellite	TD-SCDMA	

Figure 2: Priority Matrix for Wireless Networking, 2006 [21]

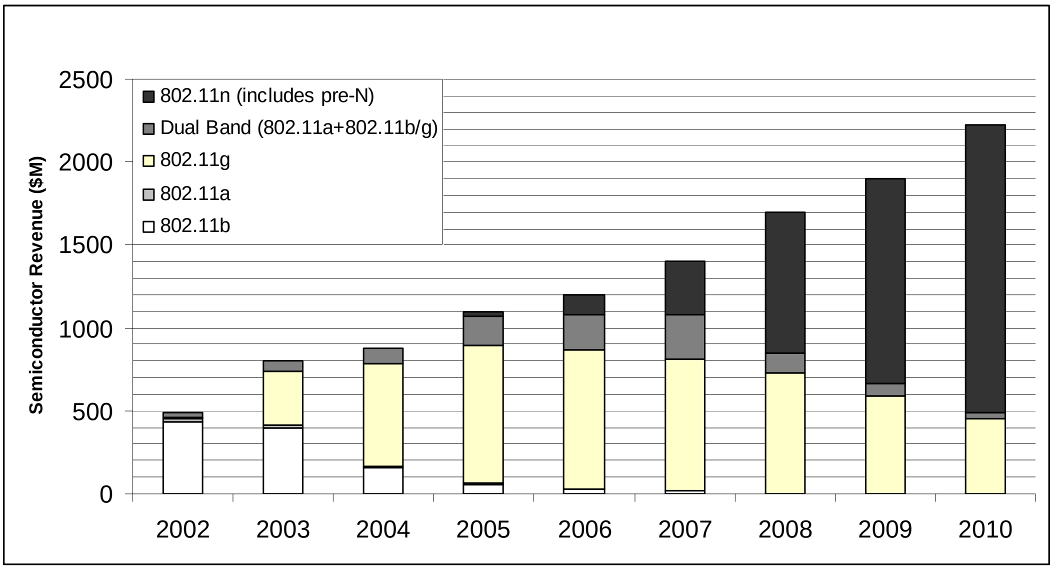

Figure 3: Revenue per Protocol [26]

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

This section provides information on the updated characteristics of technologies considered above.

5.2.1. IEEE 802.11n

IEEE 802.11n is on the way. In January 2007, the IEEE 802.11n working group has approved draft 2.0. The actual timeline for ratification of a full 802.11n standard is targeting September 2008 for final approval [15].

In the opinion of Höchel-Winter [14] market-ready products will not be available before final approval of specification. However, so-called "draft-n" devices, which are built on top of some draft version of the standard, are already in the market.

According to the draft specification, future changes would only affect the firmware whereas the chip should remain stable [22]. Suppan [22] sees backwards compatibility as one of the big question marks of 11n. Backwards compatibility and the integration of Voice-over-Wireless require a parallel 11g structure. This will affect the network design enormously [22].

One of the key technologies used in 802.11n that is discussed to have strong impact on the performance of wireless networks is MIMO (multiple-input multiple-output). "MIMO has the potential to boost throughput beyond that of traditional wired Ethernet connections, significantly increase the range of Wi-Fi devices, and dramatically improve quality of service (QoS)" [26].

5.2.2. Wireless Mesh Networks

The next evolutionary step in mesh topology networks could be extensively decentralised and self-organizing [19]. In the future a large number of devices have to be integrated into an area-wide radio network in a flexible, cost-effective and productive way [19].

In the context of meshed networks UWEs (Universal Wireless Entities) could increase network performance. Universal Wireless Entity is a device with different receivers/transmitters and allows the use of different radio services (e. g. IEEE 802.11 a, g, n; IEEE 802.16 a, e and GSM) [19].

Kauffels [19] sees the following evolution steps in meshed networks:

Evolution	**Time horizon**	**Description**
Step 0	2006/2007	• Proprietary network • Nodes have access point functionality
Step 1	2007/2008	• Standard between nodes: IEEE 802.11s or IEEE 802.16a,e
Step 2	2008/2009	• Increasing influence of UWEs
Step 3	2009/2010	• End devices have meshed network capability • End devices are UWE devices

Actually there exists no standard for meshed networks. "There is, however, a standard on the horizon (…). It is called IEEE 802.11s, and will allow networking equipment from multiple suppliers to form and support large mesh networks [13]." The latest draft of 802.11s defines a slightly modified reactive routing protocol, AODV [20], as the mandatory protocol, and a proactive routing protocol, RA-OLSR which is a variant of OLSR [11] as optional [16]. The IEEE Standards Association assumes that standardization of IEEE 802.11s will be finished in June 2009 [15].

"In-Stat believes that because of the clarity of the ZigBee standard, the organizational strength of the ZigBee Alliance and the involvement of several of the world's largest semiconductor companies, ZigBee will emerge as the dominant wireless mesh networking technology. ZigBee is a networking layer that is built on top of the IEEE 802.15.4 standard." [18].

Recent research by In-Stat found the following [18]:

- In 2006, In-Stat estimates between 4.5 million and 10.5 million ZigBee RF components will be sold.
- Commercial building control is, and will continue to be, the largest 802.15.4/ZigBee application.

- In 2005, North America represented 53% of all 802.15.4/ZigBee nodes in use.

5.2.3. Wireless Sensor Networks

"Self-forming, self-healing, multi-hop Wireless Sensor Networks (WSN) are one of the hottest emerging technologies and are bound to revolutionise many industries. Almost every market analyst firm is following wireless sensor networks with the general consensus that more than 100 million networked wireless sensors will be shipped by 2010." [10]

The Gartner Group [21] predicts that "wireless technology for sensor networks using mesh architecture will become mature, and prices will decline, also driving adoption".

But "a major barrier to the widespread deployment of wireless sensor networks (WSN) is the lack of a common network protocol", so Forbes [12], senior analyst at ARC Advisory Group. "At present ZigBee is the only multi-vendor protocol specification in the WSN space." [10] "However it has been deployed and tested in industrial environments, ZigBee 1.0 has not been able to perform as well as (…) proprietary protocols in meeting industrial requirements." [10]

Network Layer	**Standard developer**
ZigBee	ZigBee Alliance
Proprietary (multiple)	Accutech, Dust Networks, Ember, Millennial Net, Sensicast Systems
ISA SP100.14	In process by ISA
IPv6	In process by Invensys, others
Wireless HART	HART Comm. Foundation

"WSNs are attractive in factories as a replacement for wired sensors", says Harry Forbes. "Even if the WSN node costs hundreds of dollars, it is still less expensive than installing a wired sensor node (…)." [10]

WirelessHart

The HART® Communication Foundation (HCF) has released the HART 7 Specification. The HART 7 Specification enables many new capabilities for communication with intelligent field devices including WirelessHART™, the first open wireless communication standard specifically designed for process measurement and control applications. The HCF membership approved the HART 7 Specification in June 2007, following an extensive review and approval process. The HCF Board of Directors authorized release of this new standard on September 7, 2007.

5.2.4. Other Wireless Technologies

In September 2007, the HART Communication Foundation approved the specification for WirelessHART™ Communication, Products are expected early 2008.

The University of Applied Science in Bochum, Germany, examined the Capability of Bluetooth for Real-Time Transmission in Automation. According to the researchers "the applied channel codes of the Bluetooth specification are insufficient for real-time transmission on the identified communication channel. Furthermore a non-eligible amount of lost data packets was ascertained, which was probably caused by the receiver-side failure to synchronise on the data packet preamble." [25] "A fast jitter free and determined data transmission in the region of 10ms seems to be impossible." "The potential of Bluetooth systems in time critical areas of communication, e. g. the industrial real-time communication, is a challenge for research and development." [25]

WiMedia UWB

Since 2005, WiMedia alliance has announcing the ultra-wideband (UWB) common platform [17]. The platform is designed to operate with application stacks developed by the 1394 Trade Association Wireless Working Group, the Wireless USB Promoter Group and the Bluetooth-SIG. The platform structure allows peaceful coexistence with other wireless services (**Figure 4**)

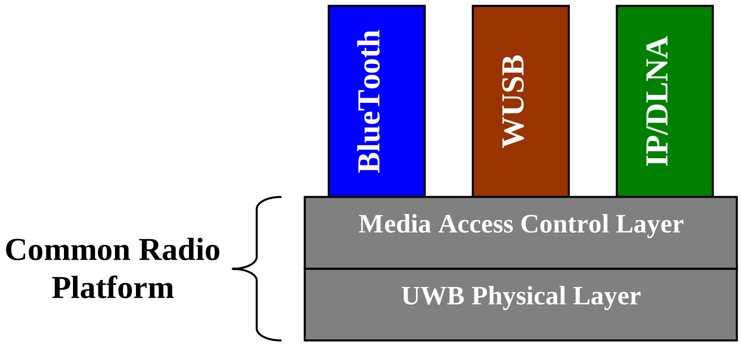

Figure 4: Common UWB platform

In March 2007, the WiMedia Alliance announced that the Ecma International standard for ultra-wideband technology, elaborated from the WiMedia UWB Common Radio platform, which has been approved for release as an ISO/ IEC International Standard [9]. The ECMA-368 standard, titled High Rate Ultra-Wideband PHY and MAC Standard, was approved as ISO/IEC 26907, which specifies a distributed medium access control (MAC) sublayer and a physical layer (PHY) for wireless networks. The PHY and MAC specified in this Ecma standard are compatible to high data rate communications between a diverse set of mobile and fixed electronic devices. The standard enables products powered with UWB technology to exist and operate worldwide.

In June 2007, 28, Inc., the Certified Wireless USB technology leader for mobile UWB WiMedia solutions, has announced the first world's ultra-wideband solution (AL5000 Family) able to meet all regulatory requirements worldwide for applications based on Certified Wireless USB, Bluetooth and WiMedia [28]. The AL5000 Chipset is able to transmit and receive WiMedia band groups one, two, three, four, five and six which span frequencies from 3.1 to 10.6 GHz. The chipset enables penetration of UWB technology to worldwide markets including the United States, Europe, Japan, Korea, and China, and which have different UWB regulatory requirements.

Wireless USB

Wireless USB is based on the WiMedia Alliance's Ultra-WideBand (UWB) common radio platform. Nowadays, there are several companies, which provide development platform and boards, software and drivers for the evaluation and development of Wireless USB applications. In April 2007, Synopsys, Inc. releases the first USB hub, based on Wireless Host Controller Interface [27]. It is expected that many commercial products based on WUSB (multimedia consumer electronics, PC peripherals and mobile devices) comes to the market very soon. In October 2007, an update of the Wireless USB specification (v1.1.) has been released on the Wireless USB Implementers Forum in Amsterdam. Among others, this update specifies more sophisticated ways for power savings.

WiMax

Since there are hundreds of successful deployments of this standard-based technology worldwide, the WiMax can be considered as a mature technology.

RFID

Although RFID standards are being evolved, there are still cost and security aspects of tags that have to be considered [13]. Nevertheless, this technology has high potential for development and applications.

5.3. References

5.3.1. List of conferences covering relevant topics

Acronym	Description	Contact
EW	13th European Wireless Conference	http://www.ew2007.org/
ICWMC	3rd International Conference on Wireless and Mobile Communications	http://www.iaria.org/conferences2007/ICWMC07.html
	2007 Wireless & Mobile Expo and Conference	http://www.wowgao.com/2007wirelessandmobile/
WCNC	IEEE Wireless Communications & Networking Conference	http://www.ieee-wcnc.org/2007/
IWCMC	International Wireless Communications and Mobile Computing Conference 2007	http://dropzone.tamu.edu/~xizhang/IWCMC07/IWCMC07.htm
SECON	4th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks	http://www.ieee-secon.org/2007/
WiMAN	1st IEEE International Workshop on Wireless Mesh and Ad Hoc Networks	http://www.cs.iusb.edu/%7Eliqzhang/WiMAN2007/index.htm
	WLAN Mesh 2007	http://www.upperside.fr/wlanmesh2007/wlanmesh2007intro.htm
	Wireless/WIFI Convergence Conference 2007	http://www.upperside.fr/wirelesswifi2007/wirelesswifi2007intro.htm
RFID	IEEE International Conference on RFID 2007	http://www.ieee-rfid.org/2007/default.asp
WWSNA	International Workshop on Wireless Sensor Networks 2007	http://www-users.cs.umn.edu/~tianhe/WSNA07/
MOBICOM	13th International ACM Conference on Mobile Computing and Networking	http://www.sigmobile.org/mobicom/2007/

5.3.2. Relevant publications

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

Reference	Document Title and URL	Revision
First Wireless Standard Emerging from the Industry for the Industry	http://www.isa.org/source/ISA100.11a_Release1_Status.ppt	Update, Release 1
WirelessHART Standard Approved and Released	▪ http://www.hartcomm2.org/hcf/press/pr2007/hart7released.html ▪ http://www.hartcomm2.org/hart_protocol/wireless_hart/hart7_overview.html	HART 7.0 Specifications

5.3.4. Relevant product announcements or links to company statements

Company name	Product name and description	Contact
DUST NETWORKS	RESEARCH INNOVATION PROGRAM: Research Development Kit and Online Support Community Foster Innovation in Wireless Sensor Networking	ecollopy@hoffman.com
	Embedded Wireless Sensor Networking Solution For WirelessHART Standard	dustnetworks@hoffman.com

6. Device profiles of devices connected to industrial communication networks

6.1. Overview of progress discovered

6.1.1. OPC UA becomes a standard

IEC 62541 becomes the standard of OPC UA. This activity has been started 2007 under the umbrella of IEC 65E.

6.1.2. EDD/FDT integration into OPC UA

The large fieldbus user organizations PROFIBUS International (PI), Fieldbus Foundation (FF), HART Communication Foundation (HCF) and the OPC Foundation as well as the FDT Group (FDT stands for Field Device Tool, a component based field device integration technology) have collaboration in the so called ECT (EDD Collaboration Team; EDD stands for Electronic Device Description – IEC 61804-3). This group started to define extensions of EDDL and is now working on the EDD and FDT integration into the OPC UA architecture.

6.1.3. ASAM integration into OPC UA

ISO 20242 is based on the ASAM GDI (Generic Device Interface) standard, which is hold by the ASAM e.V. (www.asam.net). This organisation has the scope to standardise measurement and automation systems. The organization is mainly driven by the international automotive industry and their suppliers. ISO 20242 was started in 2001 in WG6 of TC184/SC5. The overview of ISO 20242 in part 1 is international standard since 2005, the other 4 parts are in the voting phase.

The specification is based on an interface technology, which provides profiles of measurement and general automation devices. It is mainly used in service stations of the automotive manufacture. VW for example has fully applied the standard and runs 20 000 installations.

ISO 20242 was dedicated to the beginning to the Computer Aided Testing area. Japanese activities in the project MICX (Manufacturing Information Collaboration using XML) and the integration of some results into ISO 20242 enlarge the focus of the standard also to discrete manufacturing. Overlapping with OPC UA is therefore arising.

There are first activities for the integration of ISO 20242 and OPC UA. The German NAM (Normungsausschuss Maschinebau) is settling up a related working group.

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

6.2.1. Impact of EDD integration into OPC UA to SOCRADES

There is no official publication at conferences and journals up to now describing technical details. ECT has released an EDD integration specification which is referenced below. FDT integration is still under consideration and has not yet a released specification. Therefore main architectures and features can not be reported here. ifak has some activities in specific aspects of these activities.

There are the following relations to the SOCRADES approach:

- OPC UA is already in the scope of SOCRADES MES/ERP integration because it is based on WS interface.
- EDD integration means that online information of real field devices are accessible with all details from host applications
- Standard profile EDDs allow to access field devices data manufacturer independent
- Typical devices with EDDs are process control devices such as transmitters and actuators as well as drives.
- The planned FDT integration expands the range of field devices which can be integrated into OPC UA and therefore can be accessible from MES/ERP hosts.

6.2.2. Impact of ASAM and their OPC UA integration to SOCRADES

Automation industry is a large and very innovative domain and therefore very interesting for automation manufacturers. It seems that they are using specific standards in this domain. Main IT trends are under consideration. Additional investigations and discussions with the related responsibilities are recommendable.

6.3. References

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

Reference	Document Title and URL	Revision
EDD for OPC UA	EDDL Cooperation Team (ECT) FF-690 - EDDL Phase 2 OPC UA Client Applications Step 1 Information Model, Version 1.0, September 13, 2007.	
ISO 16100	Industrial automation systems and integration — Manufacturing software capability profiling for interoperability Part1: Framework Part 2: Profiling Methodology Part 3: Interface protocols and templates Part 4: Conformance test methods, criteria, and reports Part 5: Methodology for profile matching using multiple capability class structures	

6.3.2. Network activities

Acronym	Subjects covered	Status and results	Contact
ASAM e.V.	Se above	See above	www.asam.net

7. Engineering of distributed systems

The domain of distributed systems is constantly evolving based on market changes and customers' demands. This section outlines some of the recent changes in engineering systems within the SOCRADES domain, in accordance with the state-of-the-art reported in deliverable 1.1. The areas covered include:

- Control level application engineering
- Communication and network engineering
- Business application engineering
- Overall systems engineering

7.1. Overview of progress discovered

7.1.1. Control level application engineering

An open factory automation model is proposed by Carpanzano [29] where the control logic is structured on different hierarchic levels according to the factory's functional decomposition in areas, cells and units. This approach is based on an object-oriented distributed intelligence concept, thus it simplifies the definition of complex controls, improves the reusability and enhances the system re-configurability. Each level within the control logic definition consists of three parallel functional branches such as forward control functions, nominal feedback functions and non-nominal feedback functions. Furthermore, a functional model is described for each dynamic module based on the IEC 61499 standard.

Some of the trends identified in the domain of application engineering are:

- The adoption of self-adaptive functional design with respect to the real industrial applications. The ultimate aim of such an approach is the reduction of development efforts and times, improved reliability of automation systems, and in particular improved automation solutions reuse and reconfiguration enhancements.
- The industrial adoption of open standard automation systems architectures.
- The emergence and industrial evaluation of advanced methodologies and software tools to develop and verify factory automation systems.

The success of such innovations has the potential to transform factories from passive actors undergoing market demand to dynamic actors responding in real time to consumer needs and expectations [29].

7.1.2. Communication and network engineering

The trend towards more open, vendor-independent networking systems is continuing. Systems such as PROFINet claim to provide a vendor-independent communication, automation and engineering model [30]. The value of this approach is to achieve a considerable reduction in the configuring and start-up overhead of machines and plants. Modular plant and machine construction, in particular, are now being supported by new architectures for distributed automation and coupled with new approaches to modular programming. This can lead to the distributed intelligence, which is the core concept of solving the problems involved with distributed communication, thus the development team needs to program the communications between intelligent devices. Since the use of devices from widely differing manufacturers at the field level is quite normal, users of distributed solutions must also implement data communications beyond manufacturers' boundaries [30].

7.1.3. Business application engineering

The state of the art in business application design and integration is undergoing a transition because of increasing demands from enterprises for greater agility. Companies need to modify their applications more quickly, but find themselves burdened with huge investments in hard-to-change legacy systems. They need to adapt their systems and implement new business applications that are better suited to ongoing modification.

At least three different engineering trends are envisaged for the business application domains:

- Service-oriented architecture and event-driven architecture are becoming the dominant design styles for business applications [31]. A change is expected on applications from monolithic structures to sets of SOA modules. This architectural transformation is driving a significant change in middleware infrastructure as well.
- Middleware appliances will affect the market. By 2008, more than 40 percent of large businesses are expected to deploy a middleware appliance [31]. There will be more interest in the use of middleware, integration and messaging technologies within application architecture [32]. Relevant tools include transaction managers, object request brokers, RPC-based schemes, XML-based technologies, object transaction monitors, Web services, application integration tools, message-oriented middleware (MOM) alternatives, and publish and subscribe systems. Also emphasizes the use of middleware to link multiple packaged and/or packaged and internally developed applications, and multi-vendor DBMS systems to allow seamless integration between dissimilar systems.
- Business application integration, event processing and SOA will greatly improve real-time insight into business operations and enable better sense-and-respond systems. Low-level event monitoring and integration to the business application will help make application software more flexible and maintainable through software engineering that uses uncoupled relationships among modules.

7.1.4. Overall system engineering

The current trend in manufacturing system design tool development consists in merging system mechanical and control design software in a single environment in order to break the communication barrier that commonly exists between mechanical and control engineers and which translates into difficulties to coordinate two complexes but separated design processes. An example of such motivation in the current industry is the recent acquisition of the PLM software maker UGS, by Siemens AG specialised in control design and automation systems.

The focus of this emerging type of engineering tools, referred to as digital mock up tools, virtual manufacturing, or virtual prototyping solutions, is placed on:

- The editing of 3D-based and dynamic virtual models of the system being design in order to provide an intuitive system visualisation basis that can be used as a catalyst to enhance communication between mechanical, control and product engineers and customers' feedback.
- The editing of manufacturing system's control logic in a digital form using familiar representation (e.g. ladder, timing/Gantt chart, function block diagrams), and the capability to test the designed logic against the virtual 3D system model for (off-line) design testing/debugging.
- The enhancement of the system design process by providing support for system design and modelling data re-usability and re-configurability. This is achieved by focusing on the use of re-

usable data blocks that encapsulate control and mechanical design data, and which are referred to as component, devices, building blocks depending on the software product used.

- Integration of additional tools and data in the 3D modelling environment, and extended use of the 3D model to additional system design areas: e.g. human modelling for ergonomics studies, use of 3D model for higher level production management simulation, plant layout modelling.

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

7.2.1. Control level application engineering

To progress further in this area within SOCRADES, the main area of concentration shall be the design and development of the logic controller which needs to interact with other functional blocks (centralised and distributed), FTBs and Web services. Particularly, a specific design model has to be adopted, designed or deployed for such a development process, where the system can be defined and specified based on a structured development methodology. For example, one of such models is the Design Cycle Model as described by Carpanzano [33].

Most of the commercially oriented projects do adopt such structured methodologies and models for the system development life cycle where a clear defined boundary and functional specification is drawn. Similarly, SOCRADES requires adopting quickly a specific development approach for the control logic development.

7.2.2. Communication and network engineering

To simplify the concept of communication programming with respect to SOCRADES domain, the principle of software component technology has to be applied. Here, the user configures and programs the programmable controller or intelligent field device with the software engineering tool. A software component is then formed from the entire user software for this device [30]. The functionality of the intelligent device with the application-specific programs is encapsulated. Outwardly, only those variables needed for the machine-wide or plant-wide interaction are accessible in the form of a technological interface. This component model allows the combination of applications of widely differing origin according to the building block principle.

7.2.3. Business application engineering

New developments on business application engineering in relation with SOCRADES domain include mainly further support for SOA and web services, and tighter integration of business applications with device level operations. In this regards, major application developer such as SAP and IBM have made significant enhancement on their business applications.

For instance, SAP Netweaver's key driver in 2007 is the promise of enterprise SOA to enable business process flexibility on top of a stable core, to utilise existing investments to the largest extent possible, and to leverage new business opportunities by building and adapting composite applications [34]. Furthermore, there is a clear plan for deeper integration of SAP xMII with the SAP NetWeaver Visual Composer tool to deliver unified analytics leveraging SAP xMII as a back end in addition to SAP NetWeaver BI and other enterprise data sources. Equally important, SAP xMII will provide additional functionality to SAP ERP customers [35]. From an integration perspective, SAP xMII is the foundation of the plant-to-enterprise integration strategy for the future SAP business applications.

As another example, IBM is claiming that some of the existing "unhealthy" SOAs are a consequence of partnering with inexperienced system integrators. The company is offering services, consulting sessions and tools collectively referred to as the "IBM SOA Healthcheck" to help revive life into SOAs. The promise of SOA is that data and applications can be exposed as services, which then can be reused across the organization. SOA helps create a more agile IT to meet business objectives. However, implementing and maintaining an SOA requires expertise that IT departments may lack [36]. In addition, IBM also is offering a new version of its WebSphere Business Monitor product to help companies track the performance of key business processes. The reporting capabilities of the product have been enhanced and it allows businesses to create common types of business measures and then reuse them as best practices. There are also improved tracking key performance indicators, as well as the capability to incorporate Google maps.

7.2.4. Overall system engineering

The main actors in virtual system design tools development are UGS Tecnomatix (eM-tool suite) [37] and Dassault System (Catia V5 engine-based Delmia automation tool suite) [38]. Both provide integrated environments (with central database system) and module-based software architecture that allow mechanical and control design data to be edited and integrated into dynamic models [39]. Those products come in the form of complete solutions (e.g. direct import of Catia model into the Delmia automation environment). Products such as Visual Component/V-SIM [40] are more specific. Their functions focus on 3D modelling and do not support control logic editing, but provide direct connection to OPC servers enabling simulation and testing of PLC logic against the 3D model.

All commercial products make use of proprietary formats for both 3D modelling and control logic editing which differs from one approach being investigated in the SOCRADES project that aims to maintain the system engineering data in open formats (XML, VRML) until a very late phase of the design lifecycle. However, R&D department of companies such as Delmia/Dassault are investigating the potential for lightweight model as well with technologies such as Virtools/3Dvia for enabling or online and desktop-based large-scaled interactive digital mock-ups. In the same vain, open modelling formats such as X3D is now being used by large companies (e.g. EADS Innovation Works metadata management system using a 3D model-centric) in order to develop collaborative platform to manage design data across distributed partners who use different platforms (and hence formats).

7.3. References

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7.3.1. List of conferences covering relevant topics

Acronym	Description	Contact
CIRP	International academy for production engineering	www.cirp.net
ICWS 2008	The IEEE International Conference on Web Services	See website
Impact 2008	Impact is IBM's flagship SOA conference	See website
IEEE VR 2008	virtual environments, augmented reality, and 3D user interfaces development	http://conferences.computer.org/vr/2008/prelim/

7.3.2. Relevant publications

- S. Karnouskos, O. Baecker, L. M. S´ade Souza, P. Spieß, "Integration of SOA-ready Networked embedded Devices in Enterprise Systems via a Cross-LayeredWeb Service Infrastructure" IEEE ETFA 2007 Best Paper Award, 12th IEEE Conference on Emerging Technologies and Factory Automation, September 25-28, 2007, Patras, Greece
- Patrick Waurzyniak, "Enter the Virtual World: A new generation of digital manufacturing software tools offer manufacturers a better virtual factory", Manufacturing Engineering, October 2007 Vol. 139 No. 4.
- West, R. Harrison, C. D. Wright, A. J. Carrott, 2000. The visualisation of control logic and physical machine elements within an integrated machine design and control environment. Mechatronics, no. 10, pp. 669-698.

7.3.3. Relevant product announcements or links to company statements

Company name	Product name and description	Contact
IBM	IBM SOA Healthcheck – a number of services and software which help clients with SOA health issues resulting from performance issues. WebSphere Business Monitoring – a new Globally Integrated Enterprise Assessment tool	See website
SAP	xApps Family of Composite Applications Netweaver 7.0 SAP xMII manufacturing	See website
V-SIM	V-SIM V3.0 released	dan@v-sim.com
Dassault	Boeing adopt Dassault PLM solution for production planning and assembly simulation the 787 Dreamliner	www.manufacturingtalk.com/news
Tecnomatix	Astrium Satellites selects UGS Tecnomatix	www.manufacturingtalk.com/news

8. Business process integration of networked devices related data

This section covers the latest advances regarding the integration of networked devices into business processes. We will give an overview of the progress in this field of research and describe these new solutions and approaches.

8.1. Overview of progress discovered

Integration of networked devices into business processes is not a totally new field anymore. However, we can report that the work we are currently pursuing within the SOCRADES project receives great attention by the community. Members of the SOCRADES consortium presented a paper on the 12th International Conference on Emerging Technologies and Factory Automation. The fact that this paper received the best paper award for Emerging Technologies shows that the SOCRADES project not only explores new technologies but also plays a leading role in this field.

Regarding business process modelling we discovered a very strong demand in a new graphical modelling notation. BPMN as the new quasi industry standard in graphical business process modelling is currently undergoing revision for its 2.0 version. SAP as a member of the SOCRADES consortium is also present in this standardization effort. Main issues for BPMN2.0 are the introduction of new modelling elements mainly in the area of event handling. In this 2.0 version there will be no real-world device elements, i.e., possible elements relevant to SOCRADES are not part of this effort. Still, the new version is estimated to have up to 60 elements which on the one hand gives business process engineers a great deal of flexibility, on the other hand it will introduce a new quality of complexity in regards to business process models. We will have to investigate if an integration of device specific elements into this language does actually make sense, or if a BPMN device specific dialect makes more sense.

Regarding Web Service standards, we have not discovered any bigger projects in the area of business process integration which actually focus on DPWS. Therefore it is still open if this standard will have great impact or not. Other standards, such as REST style Web Services are also promising directions which are currently analyzed by the particular communities.

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

In regards to the area of Sensor Networks, we see a great demand for high level integration of sensor data. In the community of sensor network research, which is very dominated by universities form the USA, we cannot see any efforts in standardizing uniform access to sensor network date, i.e., through Web Services. Most application driven researchers are still working with proprietary standards, and rather build the whole application every time from scratch instead of developing application frameworks which then could facilitate later application development. SAP has kick-started a working group on Sensor Networks together with major players in the domain under the SAP Enterprise Services Community umbrella. Initially a white paper that will set a common base for this domain is planned for Q1 2008. Later the focus will be to standardize services to be used commonly by enterprise (SAP) and WSN solution providers. We envision that the SOCRADES architecture and its reference implementation middleware can have significant impact in academic application development.

8.3. References

Here we are presenting a representative list of references. As research is evolving rapidly, we will report more work in the not too far future.

8.3.1. List of conferences covering relevant topics

Acronym	Description	Contact
ETFA	International Conference on Emerging Technologies and	http://www.etfa2007.org/

	Factory Automation	
IoT 2008	Internet of Things 2008	http://www.the-internet-of-things.org/
AME 2007	The Annual Conference of the Association for Manufacturing Excellence, Chicago, Illinois - October 29 - November 2, 2007	http://www.ameconference.org/Chicago/index.htm

8.3.2. Relevant publications

- Elmar Zeeb, Andreas Bobek, Hendrik Bohn, and Frank Golatowski. Service-oriented architectures for embedded systems using devices profile for web services. In 2nd International IEEE Workshop on Service Oriented Architectures in Converging Networked Environments, May 2007.
- Daniel Cachapa, Armando Colombo, Martin Feike, Axel Bepperling. An Approach for Integrating Real and Virtual Production Automation Devices Applying the Service-oriented Architecture Paradigm. 12th International Conference on Emerging Technologies and Factory Automation, Patras, Greece, September 2007.

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

Reference	**Document Title and URL**	**Revision**
BPMN	Request for Proposals for version 2.0 of BPMN http://www.bpmn.org/Documents/BPMN%202-0%20RFP%2007-06-05.pdf	2.0