INDustrial EXploitation of the

indexys

genesYS cross-domain architecture

DOCUMENT

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02	AUDI AG	AUDI	Germany
03	Delft University of Technology	DUT	Netherlands
04	EADS Deutschland GmbH	EADS-IW	Germany
05	NXP Semiconductors Netherlands B.V.	NXP-NL	Netherlands
06	OptXware Research and Development Ltd.	OPT	Hungary
07	Thales Austria GmbH	TRSS-AT	Austria
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Revision chart and history log

Version	Date	Reason
0.1	1.9.2010	Initial Version
02	10.05.2011	Contributions by Audi, EADS, NXP, OPT & TRSS, added
03	23.05.2011	Editorial corrections
1.0	01.06.2011	Final Version, minor typo elimination

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Table of Contents

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List of Figures

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1. Purpose and Scope

The purpose of this document is to summarizue the activities performed in the course of the INDEXYS project with respect to

- **Dissemination**
- **Expolitation**
- **Standardisation.**

The partners contributed to the activities subsummed under WP 6 as described herein.

2.1 Structure of this document

Mainly the activities of the Exploitation activities are deescribed in detail here-in. The document makes reference to the Periodic Report number 1, which in detail described all INDEXYS Dissemination and Standardisation activities.

It has been avioded to copy this description into this document (see WP 6 report paragraph 3.1.6 and paragraph 5.1.3 listing the visited events).

In addition to this the Interim Report number 3 and 4 deal with reporting for this activity as well (plaese refer to the sections for WP 6).

Thus the current document forcusses on the Industrial Partners which will be in the role to perform the exploitation tasks for INDEXYS.
Thes Partners are:

- **TTTech Computertechnik AG**
- **Audi AG**
- **EADS Deutschland GmbH**
- **NXP-Semiconductors Netherlands B.V.**
- **OptXware Research and Development Ltd.**
- **Thales Austria GmbH**

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2. Partner TTT

TTT is laregly involved in INDEXYS and therefore expects several different exploitable results. In this section the four most important results are briefly outlined. Furthermore, TTT's expectation - as of today (2009-08-24) - regarding the exploitability of these results is summarized.

The overall technical focus of TTT is on "network level integration", whereas key challenges such as *dependability, composability, legacy integration, efficiency* and *flexibility* are to be tackled. TTT is involved in each of the three industrial domains of INDEXYS (automotive, aerospace and railway) which makes it possible to apply / instantiate project results within these domains.

TTTs activities target at the following R&D topics:

- **FlexRay MultiSwitch** (a network device which allows flexible arbitration of FlexRay channels among a set of FlexRay network components)
- **Static TTP Node** (a TTP smart transducer node which is implemented in hardware and acts as a cost effective RDC component)
- **SW based TTEthernet** (the instantiation of a software-based Time-Triggered Ethernet network controller on a railway controller hardware target)
- **TTEthernet Dynamic Scheduling** (a technique that allows a mixture of static, i.e., off-line scheduled, time-triggered communication channels and dynamic, i.e., on-line scheduled time-triggered communication channels based on TTEthernet)

2.2 FlexRay MultiSwitch

A FlexRay MultiSwitch device directly connects to FlexRay end-systems in a star topology and allows parallel transmission of messages from different senders at the same time (given that the receivers are disjunctive). A MultiSwitch device allows partial system changes without effecting the configuration of the remaining (unchanged) part of the system.

As of today, TTT does not offer a FlexRay MultiSwitch device and therefore plans to extend its product portfolio based on the prototype implementation from INDEXYS. This means that – in addition to ongoing development activities with project partner Audi – a FlexRay MultiSwitch is planned as a standalone product. A first product ready version might enter the market by endof 2012 or 2013.

2.3 Static TTP Node

A static TTP node will be implemented as a simple system-on-a-chip solution of an RDC which offers a standardized network connection (TTP). The TTP RDC component is basically a statically implemented network node without external host CPU. Such static TTP node includes a time-triggered communication controller, a simple communication layer for message packing / unpacking and basic I/O handling in order to interface sensors and actuators.

A prototype version of a HW based communication layer was implemented in the EC FP6 project DECOS. Within INDEXYS the current version of the HW COM prototype will be evaluated and compared with TTT's table driven communication layer (which is a statically configured TTP communication layer).

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The evaluation results are planned to be used as the basis for future productization of a static TTP node (which integrated the HW COM functionality with CPU-less I/O capabilities). Furthermore, TTT plans to exploit the results of this activity for projects with aerospace customers. A productized version of a static TTP node (which primarily targets at – but is not bound to – the aerospace field) might appear soon after the project end (i.e., by the end of 2011 / beginning of 2012).

2.4 SW based TTEthernet

TTEthernet is a novel communication protocol that has been designed with the requirements to provide temporal deterministic communication and to support standard Ethernet communication without the need to change or configure higher level communication protocols, like IP, TCP, UDP, FTP. A TTEthernet system consists of a set of computer nodes interconnected by a specific switch called TTEthernet switch. A node can be either a standard Ethernet node or a TTEthernet node. A standard Ethernet node consists of a COTS Ethernet controller and a host computer.

A TTEthernet node consists of a TTEthernet communication controller that executes the TTEthernet protocol and a host computer that executes the user application. TTEthernet nodes (end systems) can be implemented either in hardware (FPGA based TTEthernet communication controller) or by using a COTS Ethernet controller and by implementation of the TTEthernet stack on top of a COTS Ethernet controller.

Within INDEXYS TTT integrates a SW based end-system on an Intel PC based TAS Control Platform hardware target. The central idea behind this approach is to combine diversity concepts (which are researched and applied by TRSS) with capabilities for deterministic communication and composable system integration.

The benefit for TTT is twofold: On the one hand, TTT's TTEthernet product offering is extended towards the railway domain. As TTEthernet is being mainly in commercial use in aviation projects with partners from aerospace and space (e.g., NASA's Orion spacecraft), enlargement of potential market areas is definitly an oportunity which can lead to revenue increases. On the other hand, the application of TTEthernet network technology in other domains than the aviation can be used as a showcase to demonstrate cross-domain exploitability of TTEthernet solutions. This can give rise to exploitation of TTEthernet solutions in the automotive domain or in other domains which are not tackled in INDEXYS (e.g., consumer electronics or medical).

The productization of TTEthernet solutions which are based on INDEXYS' TTEthernet end-system instantiation can be started instantly after the project results are available (i.e., by the end of 2011). The scope of such service offering will depend on market demands which are subject to evaluation in INDEXYS (particularly wrt. the railway domain).

2.5 TTEthernet Dynamic Scheduling

Traditionally, the time-triggered part of a TTEthernet system is configured off-line. A static configuration file is loaded to the TTEthernet Switch and no changes of this configuration are possible during runtime. In order to increase flexibility, it is advantagous if parts of the time-triggered message channels can be dynamically scheduled, which means that guaranteed bandwith is assigned to a requesting end-system during runtime. Obviously, such concept of dynamic bandwidth allocation of time-triggered traffic in a TTEthernet system must not infringe the predictability of existing time-triggered communication channels.

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Within INDEXYS, dynamic scheduling concepts are investigated. TTT plans to evaluate the AVP (audio video protocol) wrt. its applicability to support a dynamic scheduling service for TTEthernet. Preliminary customer interest regarding such service is given already today. It is – however – quite difficult to predict timeline and scope of commercial exploitation of a dynamic scheduling service.

TTT therefore regards dynamic scheduling capabilities in the sense of a stronger TTEthernet product offering. This might lead to a better uptake of the technology by partners with strong requirements regarding flexibility of network technologies together with dependability requirements (such as can be expected in the automotive domain). "Productication" in the sense of offering a dynamic scheduling service for TTEthernet can start soon after the end of the project and might appear in commercial projects by 2011/2012.

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3. Partner AUDI

Audi is mostly involved in INDEXYS' WP2. In this section the two most important results are briefly outlined in the view of Audi. Furthermore, Audi's expectation regarding the exploitability of these results is summarized.

The overall technical focus of Audi is on "system level integration", whereas key challenges such as *architecture, composability, legacy integration, efficiency and flexibility* are to be tackled. Audi's activities target most at the following R&D topic:

- **FlexRay MultiSwitch** (a network device which allows flexible arbitration of FlexRay channels among a set of FlexRay network components)

3.1 FlexRay MultiSwitch

For a brief technical description cf. section 2.2.

Audi expects that this device could be a replacement for the state-of-the-art active star devices, which have to be used in FlexRay networks due to physical layer issues (length of wiring, EMI, etc.). If we can reach the goal, to extend such an active star by the switching functionality at low additional cost, and, hence, more (effective) bandwidth, we expect to have first cars with such a device in 2015.

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4. Partner EADS-IW

The EADS has developed several techniques like component and service oriented development during this project. These techniques are possible enabler for new development processes within EADS. The gained knowledge and techniques might be used in future developments of aviation systems. Of course it would be desirable to use the project technologies in short term products.

Currently, the EADS is not able to specify a program launch date for a product using the gained technologies. We estimate that the first products using techniques from the INDEXYS project will be launched 2014.

EADS was mainly involved in the aviation domain of the three industrial domains of INDEXYS (automotive, aerospace and railway). Nevertheless, the information exchange with other domains helped to reduce cost and to gain knowledge for implementing the demonstrator quickly.

The following section explains the most important development during the project.

4.1 Network Access Controller

In Integrated Modular Avionics (IMA), distributed functional computations are centralized on a group of Central Processing Modules with powerful CPUs interfacing small, easy to maintain and reliable Network Access Controllers. This state-of-the-art platform concept is widely used for safety-critical control functions of the airplane, but currently not for cabin control applications.

The network access controller has a modular based structure with generalized interfaces to the backbone and to the sub-networks. The NAC Core Module provides gateway functionality between the backbone and the sub-networks (see Figure 1).

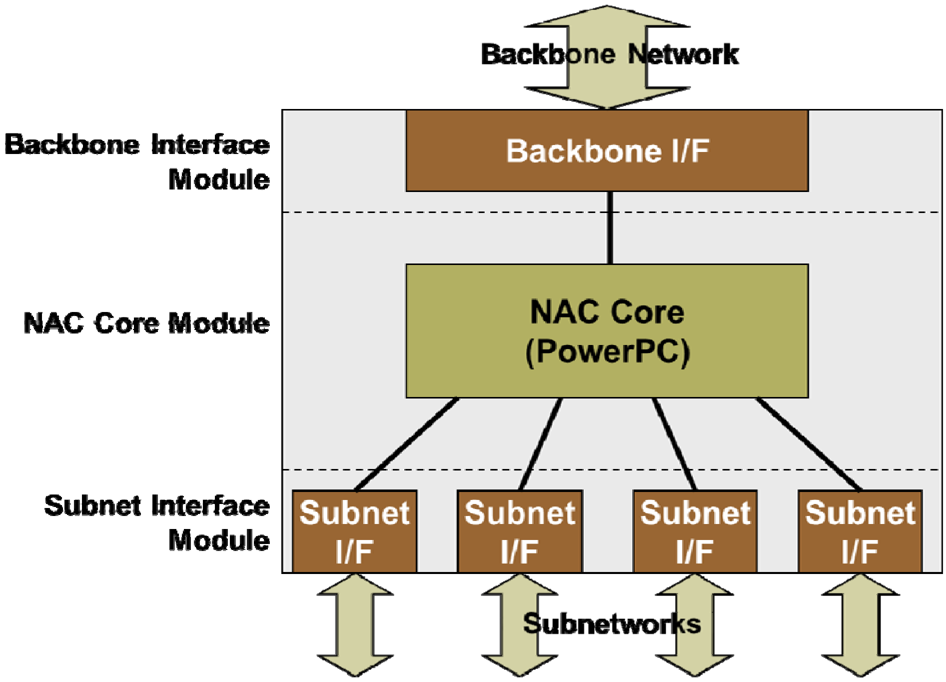

Figure 1: Block Diagram Network Access Controller

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The NAC uses open standards, such as 802.3 (Ethernet), at the physical layer. The using of such open standards has several advantages for the mentioned environment. At first, new devices can be attached in a short time into the airplane environment, because the devices and also the environment use the same language. Another advantage of open standards is that the industry can use it without additional cost and in case of IEEE standards, they are able to work together on further versions. Openness also allows changing details in the standard. This makes it possible to adapt the standard to special use cases.

As mentioned above, the NAC uses the IEEE 802.3 standard. The backbone interface implements the 802.3z (1000Base-X) standard. The subnet interface implements the 802.3u (100Base-TX).

The standard Ethernet equipment has to be modified for the usage in the cabin. To fulfill the security requirements, the standard connectors (RJ-45) are replaced through special connectors. These connectors are better protected against connection problems between.

Ethernet already implements methods, like CRC and padding, to secure the data flow. For higher level data flow, the cabin shall be able to implement further standards like Secure Socket Layer (SSL) and IPSec.

The current data rate can be easily increased by changing the Ethernet chipset in the NAC. The cabling either the optical as well the electrical cable, is able to provide higher data rates greater than 1Gbit/s. This is an investment into the future.

Naturally, it is a known fact that Ethernet is not able to provide real-time support. A meaningful utilization of such a network will lead to determinism in the sense that all timing requirements of the functions are met with the required probability.

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5. Partner NXP-NL

NXP is leading provider of in-vehicle networks solutions such as CAN and Flexray. The research deparment of NXP develops innovative proof of concept solutions that will generate new bussiness and open new markets. The **Flexray MultiSwitch** developed in the context of Indexys with lead customers such as Audi is the perfect example of that.

3.2 FlexRay MultiSwitch

NXP has developed a MultiSwitch proof of concept meeting OEM requirements and has benchmarket it with other solutions. The Automotive Bussiness Unit is assesing the technical specifications and market opportunities of this device. The results of those considerations might lead to a Fleray Multiswitch product in the market in the coming years.

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6. Partner OPT

OptXware is mainly involved in WP1 targeting the design and instantiation of platform services. The results of the work contain several items that are promising from the exploitation point of view and OptXware is planning to integrate these results in its product offering, however, currently there is no specific timing on the schedule of these products.

OptXware focuses mainly on the development tools and methods related to component-oriented system and software design and plans to strenghten its portfolio based on the following results of INDEXYS.

6.1 Automatic FlexRay scheduling

The automatic scheduling of network frames and related activities on nodes offers a productive integration environment for FlexRay-based systems. The target application domain of this technology is mainly automotive and the scheduler will be integrated to the existing Embedded Architect tool chain on OptXware.

The automatic, constraint-based scheduling algorithm developed in the current project is able to apply mathematical optimization techniques on realistic model sizes, thus eliminating the need for manual scheduling of networked systems. The user of the technology is able to supply non-functional constraints (temporal, safety, etc.) while the structure of the problem (software components, network topology, interconnections) is automatically imported from the system model. The result is a schedule for the network, and optionally also for the nodes.

The added value of this technology is a) increased productivity in network design and integration, b) formal definition and enforcement of design constraints, c) increased schedule quality.

6.2 Distributed model management infrastructure

Model management became a crucial issue in several industrial domains as the model-driven development techniques gained more importance. Team collaloration and model version management is required to provide efficient environment for large-scale model-driven projects Current methods and tools do not provide a generic, scalable solution for this problem.

The ModelServer approach developed in the framework of WP1 offers a novel method for model management. It introduces a client-server architecture to store the models in a central repository and to access them through a network in a distributed environment. The model can be edited simultanaeously by several designers and the needed automatic transformation and code generation steps can be executed on the server if necessary. The technology not only solves the problem of model handling but is also capable of the management of model transformations.

The initial version of the technology has been developed in the framework of INDEXYS and OptXware plans to rework it based on the results of the initial usability and performance test to serve a) as a stand-alone product – tool infrastructure for model-driven tools, and b) as the infrastructure of current and future modeling tools of the company.

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6.3 Cross-domain modelling methodology

A cross-domain modeling approach has been introduced in WP1. It consists of a domain-independent metamodel for component-oriented software and system design and several prototype tools that build on the metamodel.

OptXware plans to migrate its existing tools to the new appraoch in order to provide a cross-domain tool chain for its customers. The tools can be utilized in different domains and will be extended with integration adapters for the relevant domain-specific standard interchange and modeling languages. The planned tool chain will directly enable the interoperation among different application domains and the cross-domain reusability of components, models, and (sub) system designs.

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7. Partner TRSS-AT

TRSS-AT concentrates its efforts in investigating the architectural integration of diversity measures on lower system levels.

The motivation for these research efforts is twofold:

1) Introduction of Safe single Board Solutions without the burden of N-Version programming for high volume safety critical applications.

A specific research target will be the evaluation of methods for automatic generation of diverse applications from a single source base. A generic approach will be developed to provide the application engineer with platforms, methods for automated diversity and tools that allow for automated diversity as an architectural service. The bundle will enable the applications to take advantage of diversity without the burden of N-version programming. In this way the application safety case can build upon architectural measures to master:

- unknown hardware design faults,
- random hardware faults to be handled within a single hardware channel, and
- unknown operating system faults.

on a single HW channel system, which considerably reduces costs for high volume applications (e.g. trackside equipment)

2) Incorporation of COTS Hard- and Software

In the rail segment the aim is clearly to build fault tolerant systems based of and incorporating COTS hardware and software (i.e. operating system). The sheer complexity of nowadays hardware and COTS operating systems as well as the fact that implementation details of these systems are not accessible (or traceable) to the railway application engineer, mandates the introduction of diversity for those components.

To assess the impact of unknown operating system faults in non-software diverse systems, an investigation of robustness services will be carried out by research on pseudo-random behaviour of complex operating systems in the context of loosely coupled fault-tolerant architectures. The aim is to clarify the impact of loose coupling on the system's ability to tolerate intricate faults (e.g., races) in the underlying operating system. Results gained for a homogeneous hardware setup will be compared to a setup using diverse hardware, running two separate operating system instantiations for diverse processor architectures.

This will yield supporting arguments for the usage of off-the-shelf, state-of-the-art operating systems in safety-critical embedded systems without the need to employ two different operating system which would be too cost intensive to maintain.

7.1 Automated Diversity

The methodology of automated diversity will be introduced to an already identified product in the track-side systems portfolio of TRSS-AT. For this product an already existing and SIL 4 certified communication protocol for safety critical rail applications will be subject to automated diversification to render it resistent against random hardware faults without the need for active hardware replication. For this purpose it is mandartory to formally validate the approach and implementation and have it

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assessed by an external independent safety assessor. These steps are integrative part of the project. The delivery of the product is due end 2010/ beginning 2011.

7.2 Inherent Diversity and HW diversity

After the sucessful market introduction of TAS Platform [Indexys Deliverable 4.1] version 1.x currently the next major release of TAS Platform is under development. While TAS Platform 1.x was based on an in-house developed and validated operating system (process manager, file system, POSIX interface) operating on top of a micro-kernel, TAS Platform 2.0 will be entirely based on a COTS operating system (i.e. Linux). This mandates a certification strategy for COTS operating systems. The results of the research efforts aimed at inherent diversity on operating system level will be one pillar of the system safety case of TAS Platform 2.0. The release of TAS Platform 2.0 is due in mid 2011.

TAS Platform 2.0 will still be an active redundant system with uniform replicated hardware channels. However, the ever increasing complexity of COTS hardware mandates the introduction of hardware diversity on board level. Thus the (experimental) introduction of HW diversity to TAS Platform 2.x is within the scope of the INDEXYS contribution of TRSS-AT, together with a study of the implications of HW diversity on the concept of inherent diversity on operating system level in loosely coupled systems. The roadmap for field introduction of HW diverse systems is in the timeframe of 2013/2014.

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8. ANNEX A: Abbreviations

AVP	Audio-Video Protocol
COTS	Commercial-Of-The-Shelf
R&D	Research and Development
RDC	Remote Data Concentrator
SW	Software
TAS (platform)	Transport Automation System (platform), i.e., a platform from TRSS
TRSS	Thales Rail Signalling Solution
TTEthernet	Time-Triggered Ethernet
TTP	Time-Triggered Protocol

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