Networked embedded system middleware for heterogeneous physical devices in a distributed architecture

Introduction to the Hydra project

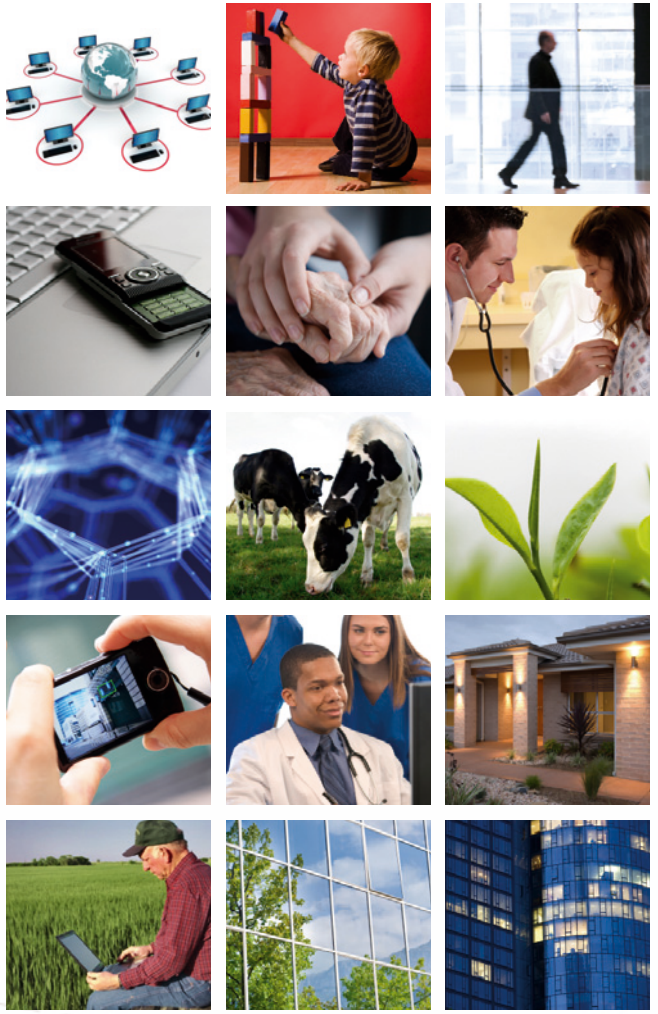
Embedded Systems are everywhere; built into health-care devices, in building automation, heating systems and home appliances, into mobile phones, cars, roads, bridges and tunnels, and even into our clothes. They are interconnected into networks consisting of many diverse devices forming the building blocks of a future Internet of Things.

Embedded Systems technologies are deployed in all relevant market sectors and have a major impact on the way these sectors work and collaborate, how they will develop, and how successful their products will be on the world market.

Manufacturers are thus increasingly seeking to network their own products with other systems in order to provide higher value-added solutions for their customers, which is often a difficult, time consuming and costly development process, in particular for small and medium sized enterprises.

The Hydra project aims to alleviate the problems that European industries are facing by researching and developing middleware for networked embedded systems that allows programmers to develop cost-effective, high-performance Ambient Intelligence (AmI) applications using heterogeneous physical devices.

To facilitate the development, a series of development tools are developed: The Hydra Software Development Kit (SDK), Device Development Kit (DDK) and IDE (Integrated Development Environment.



Application areas

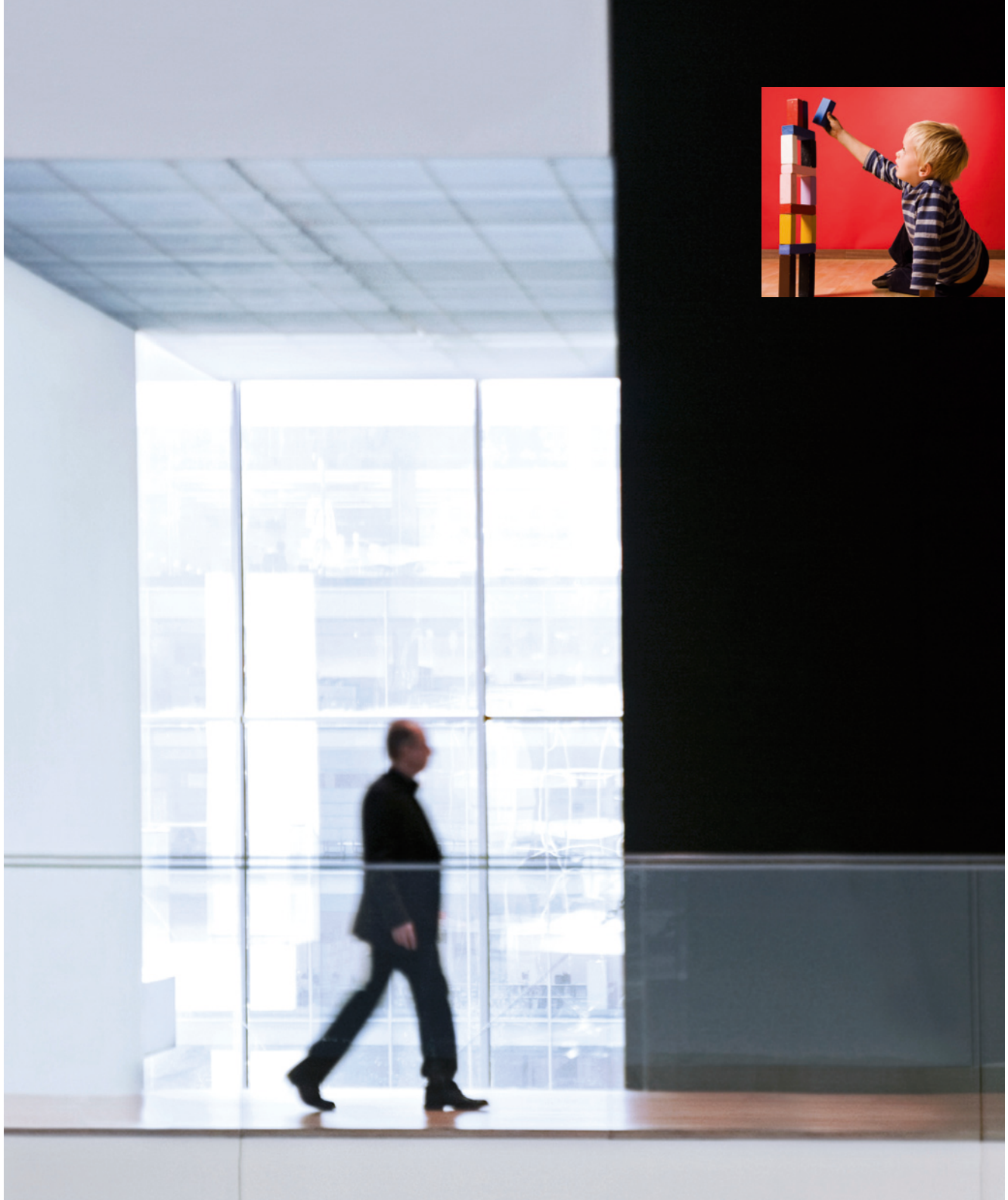
The HYDRA middleware are validated in three user domains: Building Automation, Healthcare and Agriculture.

Building automation

The field of Intelligent Buildings, Intelligent Homes and Building Management Systems encompasses an enormous variety of technologies, across commercial, industrial, institutional and domestic buildings, including energy management systems and building controls. The potential of the Hydra middleware in these markets is vast, and peoples' lives are heavily influenced from the effects of Intelligent Buildings.

A "smart home" is a completely networked, both internal and external controllable house which is electronically secured and equipped with different features and based on self-learning software. This software is setting up user profiles based on the behaviour of the different users and is automatically disposing resources at that times when they are expected to be needed by the users.

The market for professional building automation systems and components is very large and rapidly growing. A large number of companies are offering components and infrastructures for smart home concepts and home entertainment for private homes.

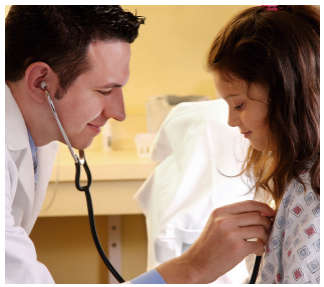


Healthcare

Public health is a key priority for the Member States and Europe is facing serious challenges in the near future of delivering quality healthcare to all its citizens at affordable costs. Prolonged medical care for the ageing society, the costs of managing chronic diseases, and the increasing demand by citizens for best quality healthcare are major factors. The emerging situation calls for a change in the way healthcare is delivered and the way medical knowledge is managed and transferred to clinical practice.

eHealth offers useful capabilities to open new opportunities in health and disease management, improve illness prevention, facilitate chronic disease management through active participation of patients and enable personalisation of care that contribute to improving the productivity of healthcare provisioning. eHealth services and the development of sophisticated personal wearable and portable medical devices will also allow patients and healthcare professionals to become more mobile and stay longer in the workforce. However, intelligent devices must be interoperable allowing them to interact with other devices and services.

A common problem for manufacturers of medical devices and for developers of eHealth systems is the lack of interconnectivity and interoperability of the various proprietary components and subsystems. The Hydra middleware will enable devices and subsystems to communicate and allow developers to develop intelligent, secure, multiparametric Healthcare services using a range of medical devices and subsystems.

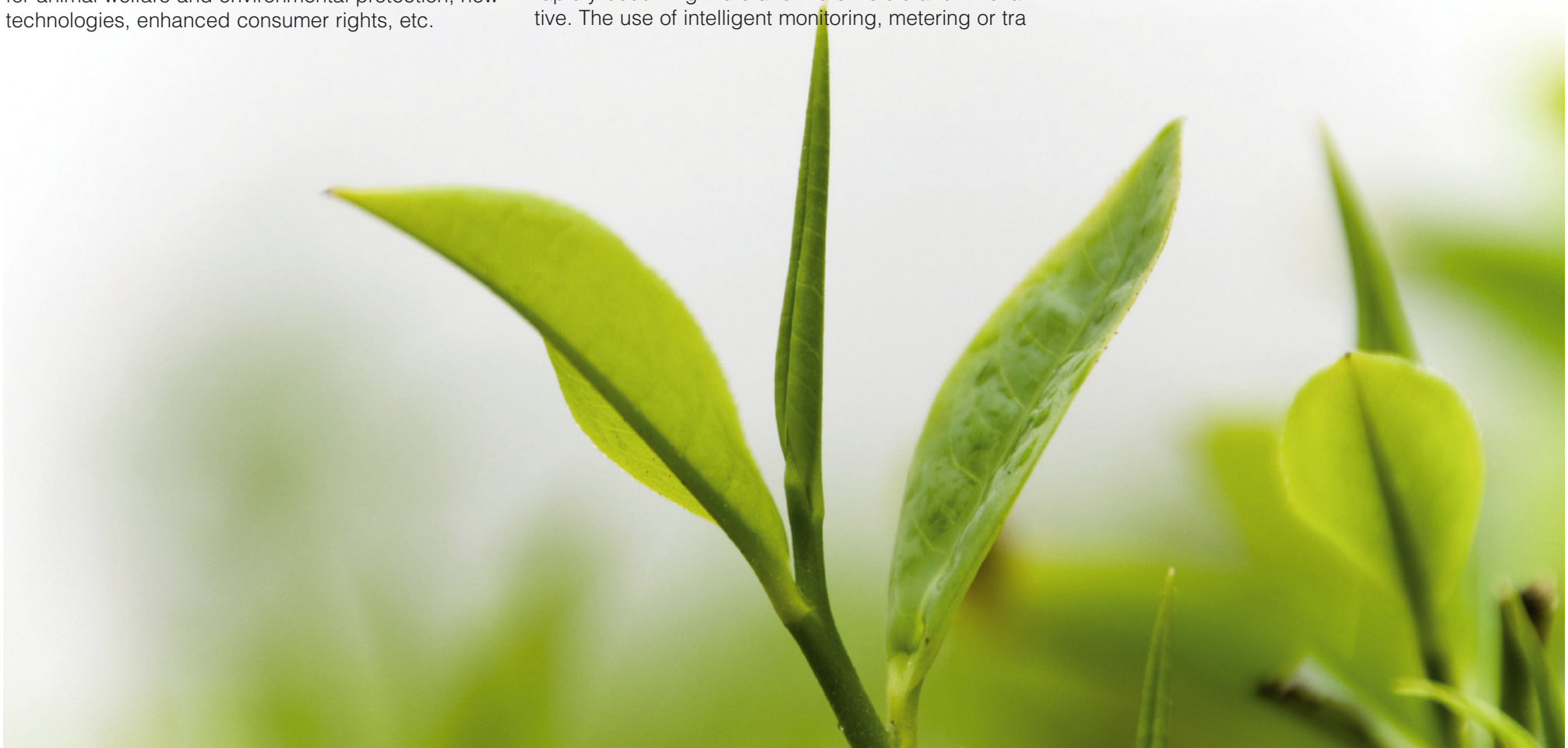


Agriculture

Agriculture is the most ancient economic activity of human beings; therefore it's commonly identified as a traditional sector and - unfortunately - very often considered a static sector, unable to actively enhance the economic and social development of our countries. The truth is that agriculture embodies a strong dynamism and will, in the coming years, face many relevant and rapid changes due to changing external factors such as: globalisation, new regulations, growing concern for animal welfare and environmental protection, new technologies, enhanced consumer rights, etc.

The agricultural industries are facing numerous challenges such as competition in the global markets and support for the complexity of interaction between agriculture and the environment, consumers demand traceability and transparency of food history, etc. Hence, the agricultural industry looks for new ICT technological tools to effectively manage production and logistics and farmers are increasingly seen as information managers.

ICT for agriculture is still in its infancy but is rapidly becoming more and more visible and innovative. The use of intelligent monitoring, metering or tracing devices using minimally invasive sensors is expected to rise. Food chain traceability will be more and more important for consumers. The Hydra middleware will support logistics data processing, intelligent decision support and interconnectivity via heterogeneous networks. It will enable devices and subsystems to communicate and allow developers to create intelligent applications where devices and subsystems cooperate to perform common tasks.



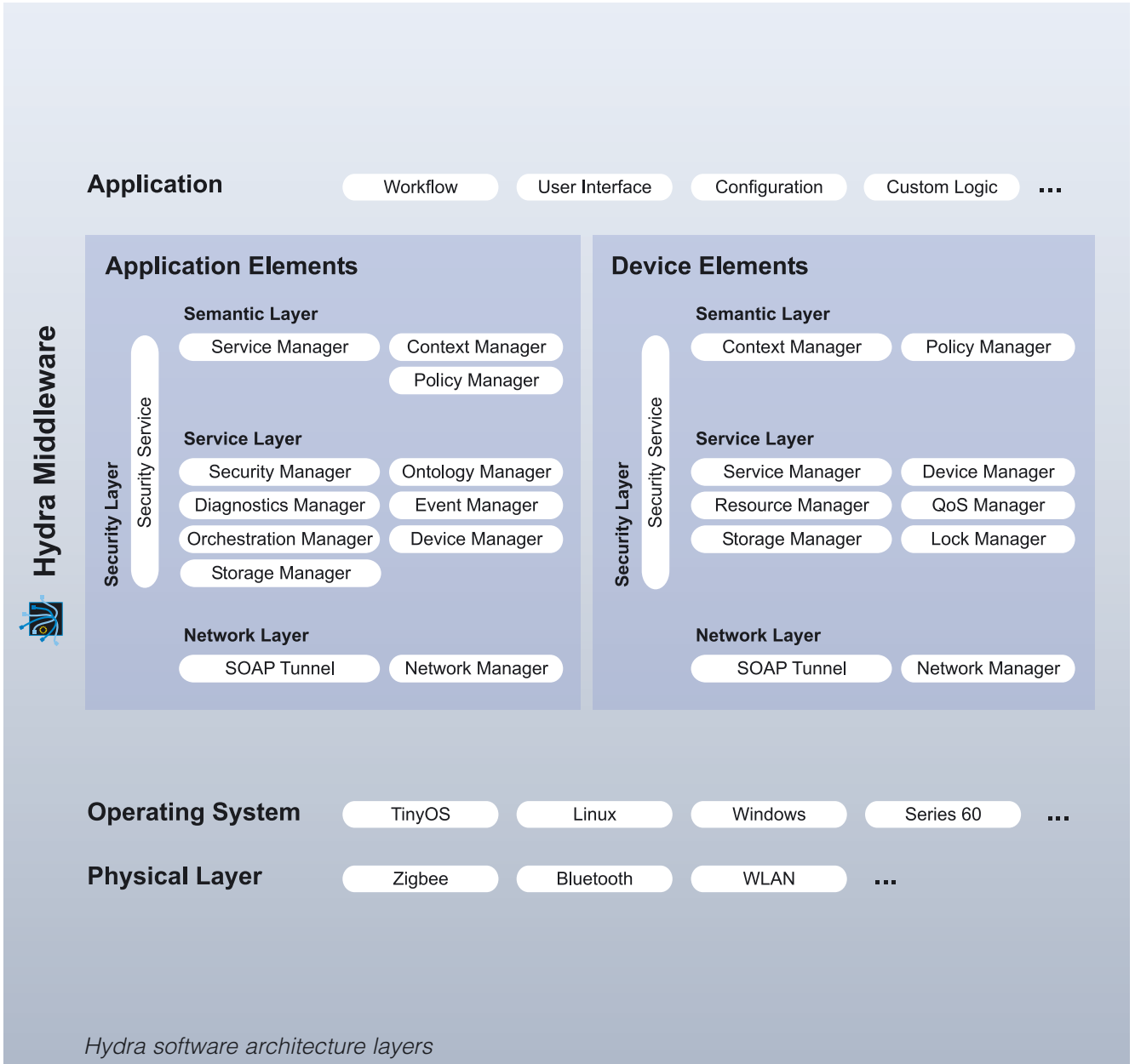
Technical overview

The Hydra middleware is an intelligent software layer placed between the operating system and applications. The middleware contains a number of software components - or managers - carefully designed to handle the various tasks needed to support a cost-effective development of intelligent applications for networked embedded systems. The middleware can be incorporated in both new and existing networks of distributed devices, which operate with limited resources in terms of computing power, energy and memory usage.

The Hydra middleware allows developers to incorporate heterogeneous physical devices into their applications. It provides easy-to-use web service interfaces for controlling any type of physical device irrespective of its network interface technology. It is based on a semantic Model Driven Architecture for easy programming and also incorporates means for device and service discovery, peer-to-peer communication and diagnostics. Hydra-enabled devices offer secure and trustworthy communication through distributed security and social trust components of the middleware.

The Hydra middleware specifically facilitates the realisation of context-aware behaviour and management of data persistence on resource-constrained devices. Context aware services can ubiquitously sense the user's environment and obtain information about the circumstances under which they are able to operate and thus adapt their behaviour in an intelligent way based on rules or stimuli.

The Hydra Software Development Kit (SDK), Device Development Kit (DDK) and Integrated Development Environment (IDE) will allow developers to create new, innovative networked embedded AmI applications and devices; quickly and cost effectively.



Hydra software architecture layers

Service Oriented Architecture

The Hydra middleware has features that allow developers to create AmI services and systems through a Service Oriented (SoA) and Model Driven Architecture approach. The network part of the Hydra middleware can interconnect devices, people, terminals, buildings, etc. with the SoA providing interoperability at a syntactic level. However, the Hydra middleware also provides interoperability at a semantic level by extending semantic web services to the device level, thus opening up for semantic interoperability of AmI applications.

Hence, the Hydra middleware offers a real novel possibility to discover even primitive resource constrained devices, dynamically embed them as Hydra enabled nodes in Ambient Intelligent device networks and provide interoperability between them.

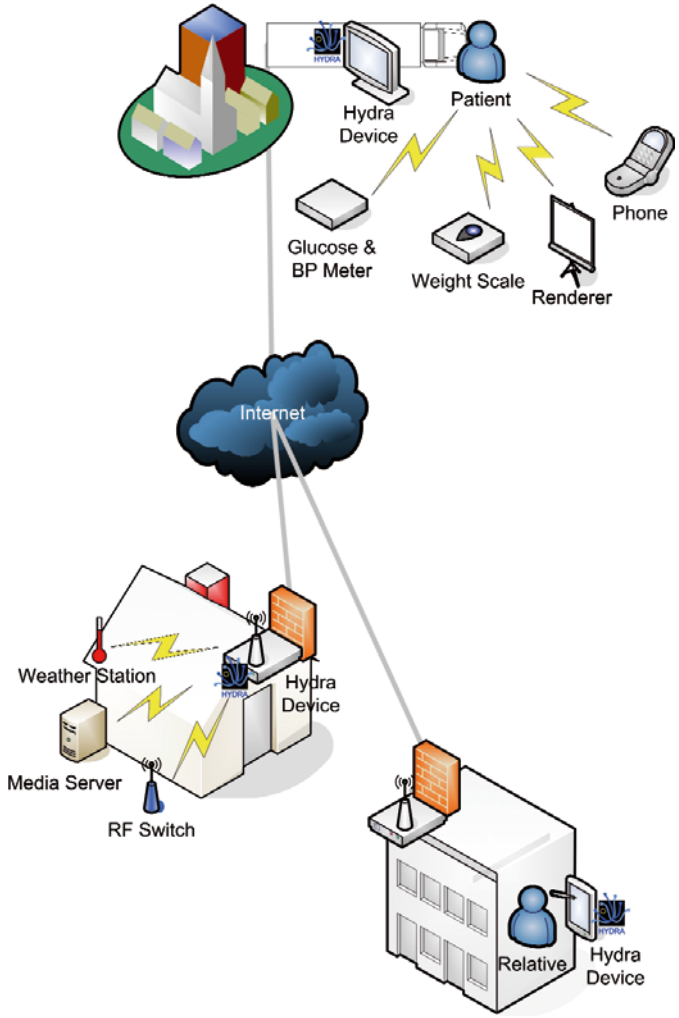
In order to achieve this extraordinary discovery capability, the device properties must be semantically described in such way that machine agents can understand and use them. In the Hydra middleware, the semantic description of devices is based on the application of ontologies employing semantic technology standards like OWL (the Web Ontology Language), OWL-S and SAWSDL (Semantic Annotated WSDL). Application domains are described in conceptual domain models and operative rules in XSLT (Extensible Stylesheet Language Transformations).

Wireless Communication and Networks

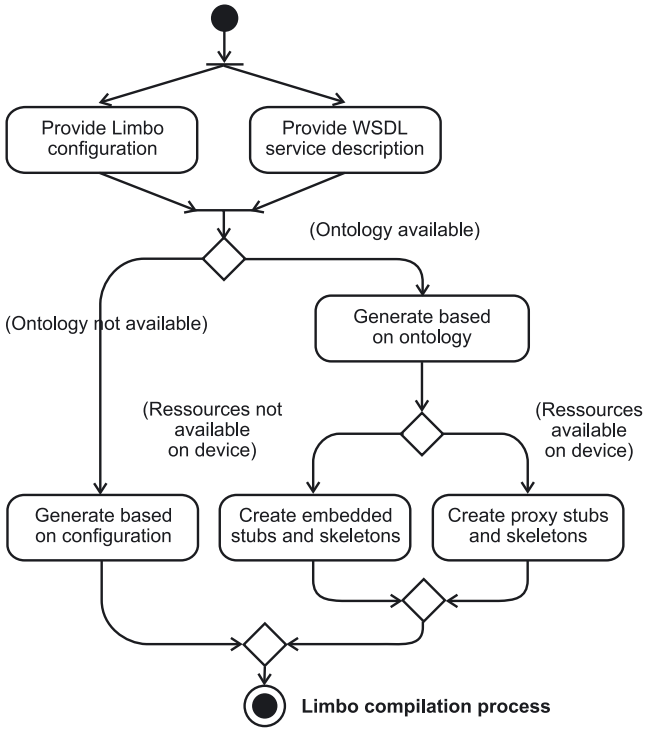
To assist application developers in addressing a wide variety of mobile and stationary devices and networks, the Hydra middleware hides device-dependent and network-dependent details and provides comprehensive open interfaces to the display, communication port, input facilities and memory management of each class of device. The Hydra middleware can also manage communication in the Hydra network, route data, register services, provide session management in the communication and synchronise the different entities in the network.

A novel implementation in the Hydra middleware is the combination of peer-to-peer (P2P) network technologies and traditional Web Service technologies allowing any device to offer, identify, and consume web services (WS) transparently from the application developer point of view. This allows application developers to consume services offered by devices in pervasive environments, even when they are located behind firewalls or Network Address Translators (NATs).

Another novel invention is the way the Hydra manages storage inside the P2P environment by providing a transparent shared memory space in the middleware, thus allowing data persistence in Ambient Intelligence applications.



A typical Hydra enabled Healthcare application with a service oriented architecture



Hydra Pervasive Web Service Compiler

Embedded Ambient Intelligence Architecture

In Hydra Ambient Intelligence (AmI) applications any physical device, sensor, actuator or subsystem can be considered as a unique web service. A major novelty in the Hydra approach is that the middleware provides support for using devices as services both by embedding services in devices and by proxy services for devices. Another novelty is that the middleware supports dynamic reconfiguration and self-configuration, which are indispensable properties in any AmI application.

The development of on-device web services is supported by an innovative pervasive web service compiler. OWL ontologies are used to make the compiler aware of its compilation context, such as the targeted hardware and software and it supports generation of state machine code on the device. Using the compiler embedded web services can now handle the variability and dependencies of hardware and software platforms while, at the same time, handle the dynamicity of frequently changing device status. Semantic rules are used to validate the dynamic configurations of the compiler.

The Hydra middleware uses SWRL (Semantic Web Rule Language) to specify self-management rules, including the constraints for configuration of components, device and system diagnosis rules, quality of service based service selection and matching, detection of service mismatching and adaptation for service matching. Self-management features are implemented with the diagnostics manager, QoS manager and other components.

The Hydra partners have published a range of scientific papers on service oriented middleware, P2P networks of physical devices, ambient intelligence, security and trust, business modelling and similar subjects covered by the Hydra project.

Please consult the website for a full list of publications.

www.hydramiddleware.eu

Trust, privacy and security

In order to solve the rapidly growing challenges of privacy, identity theft, and trust, the Hydra middleware has extensive facilities for incorporating security and trust models in AmI applications. Security goals such as confidentiality, authenticity, and non-repudiation can be addressed by a particularly trustworthy design and implementation of web service-based mechanisms, enriched by ontologies and semantic resolution techniques.

The concept behind the Hydra security meta-model is ”semantic resolution of security” focussing on moving security from being identity-based into a semantic, credentials based framework. The semantic descriptions of capabilities and certificates enable interoperability between heterogeneous devices and platforms. Different devices may use different protocols to communicate, not only for security. To enable such devices to communicate with each other without a common protocol, the Hydra middleware provides a model for semantic description of their capabilities and means for mapping these into the higher level security goals.

By defining security requirements in these higher-level semantic security goals and mapping capabilities towards the same security goals using external assurance providers, comparison and resolution between different security models can be facilitated. This enables scalable security and asynchronous security upgrades as new capabilities can be mapped towards existing implementations and the middleware facilitate the validation. Also it adds the capability of dynamic and adaptive security as hard coding of assumptions is replaced by polices and external assurances.

Another innovative approach in the Hydra middleware is a coherent no-trust context-locked separation achieved through virtualisation of devices and people. The Hydra middleware virtualisation models enable developers and end users to choose the representation of physical devices, identities, personas and services restricted to their preferences. The virtual appearance can be a reduced or enriched representation of the physical entity. The enabling novel innovation in the Hydra middleware is the use of a Hydra ID (HID) to make the notion of a virtual device by default. This invention has the double purpose of ensuring separation of underlying communication technologies and its logical representation. Moreover, it isolates the shared spaces in the middleware from the application specific semantics.

Hydra middleware in industrial use

Understanding the business ecosystem, in which the developer users of the Hydra middleware are a part of, is an essential prerequisite for the successful deployment and exploitation of new services and applications. Hence, the Hydra project also aims to demonstrate its business potential, i.e. realistic and sustainable business cases in selected domains.

Given the enormous amount of heterogeneous devices, sensors, and actuators with embedded systems already existing in the market and the diversity of producers and manufactures, there is a large need for technologies and tools like the Hydra middleware that easily can add, implement and network the functionality embedded in the devices. Since the Hydra middleware incorporates the necessary means and technical innovations for efficient development of applications and services, companies can use device networking technologies to reduce costs, reduce installation time, improve effectiveness, neutralise learning differences, bridge knowledge gaps, gain more customers, and pursue new business opportunities. Companies can also position their Hydra enabled devices into a customer service relationship that enhances both revenues and customer retention.

Hence, with the introduction of the Hydra middleware, new business models are needed to identify and explain the much more dynamic value creation and to model the exchange of products, services, information and resulting values among dynamically emerging constellations of multiple stakeholders across the business system. The ability to correctly identify the value creation and the involved actors often makes the difference between success and failure of a new eBusiness offering.

This business modelling research in Hydra involves analysis and development of realistic business cases for users and service providers based on the concept of dynamic value constellations. Emphasis is placed on defining and measuring value creation and identifying new business opportunities.

Training is an important aspect of dissemination and commercialisation of Hydra results. The project offers complete training sessions and workshops not only in the technical aspects of the Hydra middleware, but also training workshops in business modelling.

Consortium

The consortium behind the Hydra project represents an excellent partnership of academics, computer scientists, technology developers, and system integrators. The quality of the technology project partners has brought about real advancement of the state-of-the-art in networked embedded systems. Further, the large number of industrial partners, including technology oriented SME's, assures a practical approach with high focus on the need of developer users and industry at large.

IN-JET APS, BIRKERØD, DENMARK
www.in-jet.dk

In-JeT is a concept developer and system integrator in ICT technologies for Ambient Intelligence and Pervasive Computing applications and has extensive knowledge about user needs and business models. IN-JET market concepts for ICT platforms across Europe in applications such as healthcare, security and alarm services, and building control.

INNOVA S.P.A., ROME, ITALY
www.innova-eu.net

Innova S.p.A. is specialised in Technology Transfer services and assists industrial and research organisations in the implementation of their innovation strategies for the assessment and exploitation of advanced technologies and the valorisation of R&D results.

PRIWAY, KGS. LYNGBY, DENMARK
www.priway.dk

PRIWAY is providing trust & security communication products and managed security services based on empowerment of the individual and security in context design principles.

UNIVERSITY OF READING, READING, UNITED KINGDOM
www.reading.ac.uk

The multi-disciplinary Intelligent Media Systems and Services Research Laboratory (IMSS), provides a centre of gravity for interdisciplinary and collaborative research, and knowledge transfer within the School of Systems Engineering and Information Technology.

FhG - INSTITUTE FOR APPLIED INFORMATION TECHNOLOGY, SANKT AUGUSTIN, GERMANY
www.fit.fhg.de

The Fraunhofer Institute for Applied Information Technology has gained an internationally acknowledged reputation in the areas of context-awareness, adaptive and personalized systems, context modelling, mobile services, and usability engineering.

T-CONNECT S.R.L, TRIESTE, ITALY
www.t-connect.it

T-connect is engaged in research and development of wireless applications on third generation platforms (UMTS/WLAN) for mobile communications services.

SIEMENS AG, PADERBORN, GERMANY
www.siemens.com/it-solutions

Siemens IT Solutions and Services offers IT Siemens IT Solutions and Services is an internationally leading provider of information technology solutions and services, offering one-stop shopping for the complete IT service chain - from consulting to systems integration, IT infrastructure management and software engineering right through to industry specific IT solutions.

CNET SVENSKA AB, DANDERYD, SWEDEN
www.cnet.se

CNet is a leading-edge software house specialising in semantic-based knowledge and content systems. CNet develops systems to acquire, organise, personalise and share the knowledge embedded in web, databases and multimedia content.

TELEFONICA I+D SA, MADRID, SPAIN
www.tid.es

Telefónica I+D was formed to contribute to the technological innovation of its parent company, by performing research and development activities. TID is active in major areas like: Services creation related to intelligent network and data communications, network and services management and network innovation.

TECHNICAL UNIVERSITY OF KOSICE, SLOVAKIA
www.tuke.sk

The Technical University of Kosice (Faculty of Economics and the Department of Cybernetics and Artificial Intelligence) is in its research activities specialized in semantic technologies, ontology-based knowledge modelling and knowledge systems.

FhG - INSTITUTE FOR SECURE INFORMATION TECHNOLOGY, DARMSTADT, GERMANY
www.sit.fhg.de

The Fraunhofer Institute for Secure Information Technology is one of the pioneers within the field of IT-Security and has experience in development and promotion of security technologies and in embedding of security technologies into already established applications to make them trustworthy.

UNIVERSITY OF AARHUS, AARHUS, DENMARK
www.daimi.au.dk

The Department of Computer Science has the goal to maintain a position as one of the top research centres in Europe within theoretical as well as experimental computer science. It is quite rare that a department is leading within both fields, and we want to take advantage of this position by increasing the number of cross-disciplinary activities.

UNIVERSITY OF PADERBORN, PADERBORN, GERMANY
www.c-lab.de

C-LAB (Cooperative Computing & Communication Laboratory) is a joint research and development laboratory operated by the Siemens AG and the University of Paderborn. The Paderborn Center for Parallel Computing is an interdisciplinary institute specialised in distributed and parallel computing.

Contact

This document is intended for information about the Hydra project only. The Hydra consortium makes no warranties, express, implied or statutory, as to the information provided in this document and the abilities of the Hydra middleware.

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