SEVENTH FRAMEWORK PROGRAMME

REACTION

Remote Accessibility to Diabetes Management and Therapy in Operational Healthcare Networks

REACTION (FP7 248590)

D10-1 AmI test bed

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Abstract	This deliverable presents an introductory exposition to the Ambient Intelligence vision and relevant technologies. It also provides information on theAmI Facility of FORTH-ICS that will be used to test and demonstrate the REACTION components and platform in a such intelligent environment.
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1. Executive Summary

The concept of **ambient intelligence** or **AmI** is a vision where humans are surrounded by computing and networking technology unobtrusively embedded in their surroundings that are sensitive and responsive to the presence of people. In concrete terms, ambient intelligence is provided by a large number of small, intelligent devices, ´in-built´ into our surroundings. These devices have three important characteristics: they can be personalized, they are adaptive and they are anticipatory.

An AmI setting could therefore be a perfect environment for the management of patients with diabetes where different devices measure all the health and environmental parameters of interest and a decision support system adapts and provides the proper feedback based on the patient's status. In order to test and get some experience on such an application, the FORTH-ICS AmI Facility will provide a testbed for a REACTION inspired demonstration. The AmI Facility at FORTH includes an "intelligent living room" that will be used to test and demonstrate the operation of the REACTION components and platform in general in an AmI setting.

2. Introduction

According to its description of work the REACTION project will demonstrate a new context aware, closed-loop monitoring platform which can improve productivity of healthcare systems by facilitating better integrated care and management of chronic diseases at the point of need, both in hospitals and in the private sphere. The primary disease target is insulin-dependent type 1 diabetes which requires careful blood glucose monitoring of the relevant patients. The REACTION platform aims therefore to deliver services that will facilitate continuous, contextualized and personalized care solutions for chronic disease management.

The need for continuous monitoring of various vital parameters, the patients' physical activity and health status, and the daily patients' management of diabetes in order to reduce diabetic acute and chronic complications implies the existence of intelligent sensors and glucose monitoring devices that constantly check and supervise the patients. Such continuous monitoring is feasible only when the needed apparatus is always in the vicinity of the patient, either as wearable devices or as smart appliances in the patient' sphere. In the latter case intelligent monitoring devices can provide a lot more information, such as information about his general health conditions, the lifestyle, and habits. This use case is therefore a perfect application area for the Ambient Intelligence (AmI).

The AmI vision describes a not so distant future where humans are surrounded by computing and networking technology which are responsive to their needs in a preemptive manner, and also adaptive and personalized to their habits and life style. An AmI setting could therefore be a perfect environment for the management of patients with diabetes where different devices measure all the health and environmental parameters of interest and a decision support system adapts and provides the proper feedback based on the patient's status. Such an intelligent environment could enhance the REACTION platform to support pro-active long term management of type 1 and type 2 diabetes and reduce risk of developing long term complications. For these reasons the REACTION components will be tested and integrated in an AmI environment before the actual deployments in the field trials. This testing is necessary in any case, but experimenting with the AmI technologies the future of the platform the REACTION projects aims to deliver is better secured and validated.

For this testing an AmI environment is necessary and the FORTH-ICS AmI Facility, which is currently under development, will provide a testbed for a REACTION inspired demonstration. In particular the AmI Facility at FORTH includes an "intelligent living room" that will be used to test and demonstrate the operation of the REACTION components and platform in general in an AmI setting. Nevertheless the integration entails a certain level of interoperability between the AmI facility and the REACTION infrastructure. The REACTION components will base their implementation on the Hydra middleware that will provide the abstraction layer and various infrastructural services and consequently an integration bridge between the Hydra software and the AmI Facility is necessary which will be built by FORTH-ICS in a parallel to the project effort.

In conclusion, this document aims to give a general introduction to the Ambient Intelligence vision and technologies, and a description of the AmI Facility at FORTH-ICS in particular. Additionally, an introduction to the Hydra middleware is provided as a reference point for the subsequent developments according to the project's plan.

3. What is Ambient Intelligence

The concept of **ambient intelligence** or **AmI** is a vision where humans are surrounded by computing and networking technology unobtrusively embedded in their surroundings that are sensitive and responsive to the presence of people. In concrete terms, ambient intelligence is provided by a large number of small, intelligent devices, "in-built" into our surroundings. These devices have three important characteristics: they can be personalized, they are adaptive and they are anticipatory. A personalized device allows people to change its behaviour to suit their own individual wishes. Adaptivity means that activity is also tailored to individual needs, but in this case behaviour is recorded and the activity automatically adapts to the peoples' preferences.

Ambient Intelligence implies a seamless environment of computing, advanced networking technology and specific interfaces. It is aware of the specific characteristics of human presence and personalities, takes care of needs and is capable of responding intelligently to spoken or gestured indications of desire, and even can engage in intelligent dialogue. Ambient Intelligence should also be unobtrusive, often invisible: everywhere and yet in our consciousness – nowhere unless we need it. Interaction should be relaxing and enjoyable for the citizen, and not involve a steep learning curve[1].

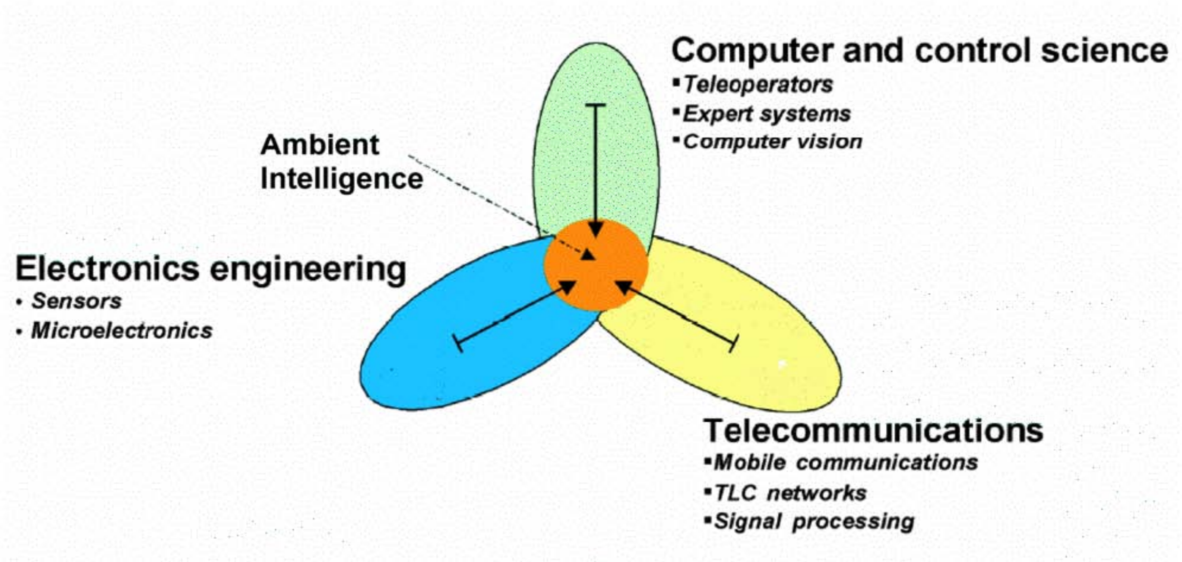


Figure 1: Emerging ICT trends [2]

The metaphor of Ambient Intelligence (AmI) tries to picture a vision of the future where all of us will be surrounded by intelligent" electronic environments, and this ambient has claims to being sensitive and responsive to our needs.

The wide array of perspectives described in the four Sections strengthens the importance of AmI as an advanced and intelligent human-computer interface. As this approach continues to develop, it is largely expected a wider comparison with existing methods. In order to achieve this goal, an interdisciplinary approach is essential. Moreover the integration of knowledge coming from different disciplines, such as clinical social and cognitive psychology, neuroscience, ergonomics, multimedia development, or communication engineering, will be crucial to incorporate ongoing insights from these fields into powerful future-generation AmI applications.

In order for AmI to become a reality a number of key technologies are required:

- Unobtrusive hardware (miniaturisation, nano-technology, smart devices, sensors etc.)
- A seamless mobile/fixed web-based communication infrastructure (interoperability, wired and wireless networks etc.)
- Dynamic and massively distributed device networks
- Natural feeling human interfaces (intelligent agents, multi-modal interfaces, models of context awareness etc.)
- Dependability and security (self-testing and self repairing software, privacy ensuring technology etc)

Briefly, systems and technologies need to be sensitive, responsive, interconnected, contextualized, transparent and intelligent.

The vision of AmI is characterized by two key features: intelligence and embedding. The feature of “intelligence” refers to the fact that the digital environment is able to analyze the context, adapt itself to the people and objects that reside in it, learn from their behavior, and eventually recognize as well as express emotion. The feature of “embedding” means that miniaturized devices will increasingly become part of the invisible background of peoples’ activities, and that social interaction and functionality will move to the foreground [3].

The concept of Ambient Intelligence provides a vision of the Information Society future where the emphasis is on user friendliness, efficient and distributed services support, user-empowerment, and support for human interactions. People are surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects and an environment that is capable of recognizing and responding to the presence of different individuals in a seamless, unobtrusive and often invisible way. The vision of AmI assumes a shift in computing from desktop computers to a multiplicity of computing devices in our everyday lives whereby computing moves to the background and intelligent, ambient interfaces to the foreground.

4. AmI Enabling Technologies

From a technological point of view, Ambient Intelligence is a particularly complex, multi-faceted and demanding scientific domain, requiring the presence and seamless integration of most of the key technologies existing today, thus posing numerous challenges in several research areas and requiring large scale experimentation.

In order to implement an AmI environment two of the key technological paradigms are the Ubiquitous Computing and Communication, and the Intelligent User Interfaces, Ubiquitous Computing implies the integration of microprocessors into everyday objects like furniture, clothing, white goods, toys, even paint. Ubiquitous Communication enables these objects to communicate with each other and the user by means of ad-hoc and wireless networking. An Intelligent User Interface enables the inhabitants of the AmI environment to control and interact with the environment in a natural (voice, gestures) and personalised way (preferences, context).

4.1 Ubiquitous Computing and Communication

Ubiquitous computing can be defined as the use of computers everywhere [4]. Computers are made available by means of the physical environment, but in an invisible way for the user. Several computers are embedded in the environment, and available to each person that is present there. Each computer can perform the tasks for which it is prepared with little human intervention or even without requiring that the user detects its presence. Ubiquitous computing devices are not personal computers as we usually think of, but very tiny devices, either mobile or embedded in almost any type of object: tools, clothing, furniture, cars… communicating through increasingly interconnected networks.

Some people say that ubiquitous computing is the Third Wave of Computing. The First Wave was “many people, one computer”, and the Second Wave, the PC, is the era of “one person, one computer”. The Third Wave will be the era of many computers per person [5]. The idea of ubiquitous computing was first thought by Mark Weiser in 1998 at the Computer Science Lab at Xerox PARC. He envisioned computers embedded in walls, in tabletops, and in everyday objects. A person might interact with hundreds of computers at a time, each invisibly embedded in the environment and wirelessly communicating with each other [6].

Ubiquitous computing can be characterized by two main attributes [7]:

- Ubiquity: Interactions are not channelled through a single workstation. Access to computation is “everywhere”. For example, in one’s office there would be dozens of computers, displays, etc., ranging from watch sized Tabs, through notebook sized Pads, to whiteboard sized Boards. All would be networked. Wireless networks would be widely available to support mobile and remote access.
- Transparency: This technology is non intrusive and is as invisible and as integrated into the general ecology of the home or work place as, for example, a desk, chair or book.

In order to build a ubiquitous computing and communication platform two approaches are:

- To provide the user with mobile devices
- To distribute different devices in the environment.

4.1.1 Technologies of ubiquitous computing

Two important aspects of ubiquitous computing is the user localization support and the development of intelligent user interfaces.

User localization

Knowledge about the location of a person (and also of a device) can be useful for ubiquitous computing applications. The system has to detect the location information and present the required information to the user in the best way using the background computer system. In order to detect the user location, there are two alternatives:

a) To put sensors and cameras in the room. One possibility is to use position sensors, devices that provide its location and/or orientation to the computer. These sensors require that an infrastructure is mounted in the room such as an electromagnetic tracker.

Another kind of position sensor is the optical one. It uses visual information in order to track the user or the objects. It is possible by means of a video camera (it is in a fixed location) that acts as an electronic eye that it is "watching" the tracked user or object. Normally, this user or object will have placed a sensor device (light-sensing devices) that will be watched. Using complex computer vision techniques based on what the camera sees, it will be possible to calculate the user or object position.

If the user or object have a single sensor device, their position will can be reported in only two dimensions but without depth information. Nevertheless, this problem can be solved if the user or object has multiple sensors. In this way, the system can triangulate the location and/or orientation of the tracked entity, providing three-dimensional position information.

b) To put all the detection and sensing hardware on the person, requiring no environmental infrastructure at all. One possibility is to provide the user with a GPS receiver. The GPS (Global Positioning System) is a "constellation" of 24 well-spaced satellites that orbit the Earth and make it possible for people with ground receivers to pinpoint their geographic location. The location accuracy is anywhere from 100 to 10 meters for most equipment. Accuracy can be pinpointed to within one meter with special military-approved equipment. GPS equipment is widely used in science and has now become sufficiently low cost so that almost anyone can own a GPS receiver. Unfortunately GPS does not work indoors. For this case other technologies like RFID or Bluetooth can be used to provide more fine grained localization information.

4.2 Intelligent User Interfaces

Intelligent user interfaces should feature the following properties [8]:

- Multimodal input – they process potentially ambiguous, impartial, or imprecise combinations of mixed input such as written text, spoken language, gestures (e.g., mouse, pen, dataglove) and gaze
- Multimodal output – they design coordinated presentations of, e.g., text, speech, graphics, and gestures, which may be presented via conventional displays or animated, life-like agents.
- Interaction management – mixed initiative interactions that are context-dependent based on system models of the discourse, user, and task. This new class of interfaces promises knowledge or agent-based dialogue, in which the interface gracefully handles errors and interruptions, and dynamically adapts to the current context and situation. The overarching aim of intelligent interfaces is to both increase the interaction bandwidth between human and machine (e.g., by increasing interactive media and modalities) and at the same time increase interaction effectiveness by improving the quality of interaction. For example, by explicitly monitoring user attention, intention, and task progress, an interface can explain why an action failed, predict a user's next action, and warn a user of undesirable consequences of actions, or suggest possible alternative actions.

Several areas are worth highlighting as key interface trends to watch. These include the growth of agent communication languages, the introduction of affect into the interface, and the growing focus on awareness and knowledge management.

- Intelligent Interface Agents.. Advances in tools and techniques for control of knowledge rich components is being advanced by specific architectures such as the Open Agent Architecture [9] but also by government initiatives such as the Distributed Agent Markup Language (www.daml.org) and the semantic web [10]. The major factors that distinguish Interface Agents from any other IUI is the fact that agents are proactive and enjoy a degree of autonomy. This role may involve actively seeking information with the filtering is undertaken with limited or no intervention on the part of user. Actions: (a) Assisting the user in communicating their task to the rest of the system (b) Learning the user profile. (c) Selecting for presentation components of the system's functionality. Issue of personification [11][12][13].

- Affective interfaces. Recognizing and expressing mood and emotion via the interface has received increased interest. Affective Computing is defined as “computing that relates to, arises from or deliberately influences emotions” [14]. This could come, for example, in the form of detecting delight or stress via language, speech, and gesture or expressing emotional displays via interactive life-like agents. It could also be as practical as detecting and effecting drowsiness in a car driver interface.
- Awareness. The explosion of Instant Messaging (IM) and associated presence information has increased user desire for information regarding user identity, physical and virtual location, activity (e.g., idle, working), availability, and communication capability (e.g., platform, interactive devices, network connectivity). In addition to Awareness of individual characteristics, there also is a need for awareness of the emergence and tracking of group activity and roles participants play (e.g., who is the leader, facilitator, key contributor)
- Knowledge Management. Strongly related to awareness are areas necessary to support knowledge access, including:
    - Expert Discovery: Modeling, cataloguing and tracking of distributed organizations and communities of experts.
    - Knowledge Discovery: Identification and classification of knowledge from unstructured multimedia data.
    - Knowledge Sharing: Awareness of and access to enterprise expertise and know-how.

4.3 AmI Application Domains

The AmI technologies can be proven to be very useful in a large number of potential application areas:

- *Healthcare and social support:* AmI provides many opportunities to support an aging population. An AmI environment is a responsive and proactive environment that enables easy participation of the individual in their own healthcare management, including communication with professional carers, friends, family and the wider community. AmI enables remote monitoring of activity and physical well-being and *e-Inclusion* for people with physical disabilities. AmI can also support the care of other vulnerable groups in society, for example by monitoring the location and safety of children.
- *Home in a networked society:* AmI has the potential to create a private domestic sanctuary -*“a place where one can lean back and be passive”*. But AmI can not only cocoon: it can also empower and enrich the individual within the home and provide additional and more flexible participation in work, learning, entertainment and family/social interactions. AmI can simultaneously help us to create a haven from the pace of modern life and provide the means whereby we can choose to ‘reconnect’ to society at times that better suit the needs and interests of the individual.
- *Modernising the social model* particularly in terms of: improving security; providing new leisure, learning and work opportunities within the networked home; facilitating community building and new social groupings; providing new forms of healthcare and social support; tackling environmental threats; supporting the democratic process and the delivery of public services.
- *Improving economy* in terms of: supporting new business processes increasing the opportunities for tele-working in the networked home; enhancing mobility and improving all forms of transport; supporting new approaches to sustainable development.
- *Community building and new social groupings:* while numerous studies indicate that the quality of social bonds is a powerful predictor of life satisfaction, people are increasingly living in a ‘mosaic’ society where they are disconnected from family, friends, neighbours and both local and national democratic structures. AmI can reinforce participation of the individual in social networks through building environments that facilitate the development of a collective, living or community memory.
- *Governance and public services***:** AmI offers many opportunities, enabling social support systems (including those related to child care, education and care of the elderly or infirm) to be delivered around the clock as befits a 24-hour economy and society. AmI also offers the possibility to

deliver 'E-Public Service' and mobile and electronic 'me' government in a mass customised and location independent way so that E-Public Service can become truly citizen, customer and business friendly, anyplace and anywhere.

- *Civil security:* AmI has the potential to make an important contribution in all phases of the risk management cycle including: risk assessment and hazard identification involving remote sensing and in-situ intelligent surveillance to inform both the individual and public services; immediate response to perceived threats requiring new decision-support systems capable of processing in near real time huge amounts of data; and damage assessment mechanisms requiring the integration of very high-resolution data with cadastral data and decision support.
- *Environment:* AmI offers the potential to move from traditional monitoring tools to more ambitious end-to-end service delivery development involving advanced forms of decision-support and knowledge management for both pollution prevention and management of resources.
- *Mobility and transport:* with AmI all 'actors' on the move, whether people or goods, can be location-aware and communicate with each other. Intelligent objects and networks for logistics can be integrated with intelligent mobile systems for people, creating Virtual Mobile Environments (VMEs). This will address both the physical fulfilment of e-commerce (through, for example, cargo-logistics) and the seamless services across networks and terminals for nomadic users, limiting the need to travel and optimising mobility. AmI will improve the safety of the vehicle, its occupants and other road users with on-board driver assistance systems and improvements in traffic management, including a reduction in congestion. In the air, advances in surveillance and communication in air traffic technologies enable more efficient and reliable air traffic control.
- *Sustainability:* AmI can be instrumental in the development of new technologies that use fewer natural resources, optimize energy efficiency, and help reduce pollution or risks to health and safety. AmI offers opportunities to reduce the impact of 'primary' effects of use of ICT by placing a greater emphasis on design for re-use and dismantling; moving away from dependence on batteries to energy on the fly; and by introducing clean manufacturing due to AmI production processes. AmI can enable beneficial 'secondary' effects by reducing and optimising physical mobility, by optimising energy usage, and by improving waste management. (The design of AmI must, however, take account of undesirable 'tertiary' effects – or undesirable consequences.)
- *Enterprise:* AmI can enable the formation of virtual enterprises, the fluid configuration of business processes, and the seamless inter-operation of underlying information systems. AmI will enable companies to participate in several networks simultaneously without the need to radically alter their company cultures and preferred methods of working.

5. The AmI Facility at FORTH

The Institute of Computer Science (ICS) of FORTH is in the process of creating a large-scale, state-of-the-art Ambient Intelligence European Facility, which will act as a research nexus for studying and developing, from a human-centred perspective, related technologies and for assessing their impact on the individual, as well as on society as a whole.

Starting with the creation of an intelligent home simulator, the AmI facility will be expanded to address specific indoor and outdoor environments, relevant application domains (e.g. housing, work, health, security, education, transportation and entertainment), as well as their related physical, social and cultural characteristics.

The AmI Facility will also provide a showcase for demonstrating the potential added-value and benefits of AmI technologies in different aspects of everyday life and activities. In this way, the AmI Facility will foster the vision of Ambient Intelligence, facilitate multi-disciplinary international collaborations and provide a focal point for technology transfer and dissemination of know-how to European industry, adding to its competitive advantage. It will also contribute towards the European strategic priority for "an Information Society that is inclusive, provides high-quality public services and promotes quality of life", while also promoting synergies and knowledge diffusion in the context of relevant European research projects and actions.

The creation of this facility builds on the scientific know-how and technical expertise of FORTH-ICS in a number of contributing critical domains such as Human-Computer Interaction, Universal Access, Artificial Intelligence, Semantic-based Knowledge Systems, Robotics, Computational Vision, Networks and Telecommunications, Information Security, Distributed Systems, Computer architecture, Microelectronics, Sensors and Biomedical Informatics. All Laboratories of FORTH-ICS are actively engaged in this effort, and collaborations are promoted with other FORTH Institutes, as well as other organisations.

In the context of promoting research in the domain of AmI, FORTH-ICS has played a key role in the establishment of the new ERCIM working group: 'Smart Environments and Systems for Ambient Intelligence'. The AmI Facility of FORTH-ICS will promote and support active collaboration and synergies among working group across Europe, by offering a technological platform and an experimental test bed for research and development activities.

The Ambient Intelligence Programme will constitute platform for cooperative research towards developing and studying AmI-related technologies and assessing their impact on the individual, as well as society as a whole, but also as a unique showcase for demonstrating the potential, added-value and benefits of AmI technologies in different aspects of everyday life and activities. In this direction, the AmI Programme aims to realise a link for technology transfer and know-how dissemination to industrial actors. Particular emphasis will be given on the simulation and experimentation with several indoor and outdoor environments of key importance, taking into account related parameters ranging from domestic and rural environmental features, to distinctive cultural and societal traits. Research and development work will be predominantly human-, rather than technology- centred and will focus on selected key application domains: housing, work, health, security, education, transport, and entertainment. Last but not least, the AmI Programme will seek to develop multidisciplinary research and promote collaboration with other research and academic organisations around the world working in this area.

5.1 Context and objectives

The AMI Programme will support research and development activities in numerous related scientific areas including, but not limited to:

- Human-computer interaction
- Networks and telecommunications
- Distributed systems
- Semantic-based knowledge systems
- Computer architecture
- Microelectronics

- Sensors
- Robotics and automation
- Computational vision

In the context the AmI Programme, the research activities will focus on six thematic areas, each related to a number of application domains. These thematic areas will also act as: (a) inspiration drivers for envisioning realistic, meaningful and added-value application scenarios for AmI technologies; and (b) test-beds for assessing and validating constituent AmI technologies in simulated real-life contexts. The selected thematic areas represent both private/restricted and public environments and include (Figure 2):

- Home: Intelligent living room
- Work: Intelligent Office
- Education: Intelligent classroom
- Transportation: Intelligent transportation
- Commerce: Intelligent exhibition
- Leisure: Intelligent playground

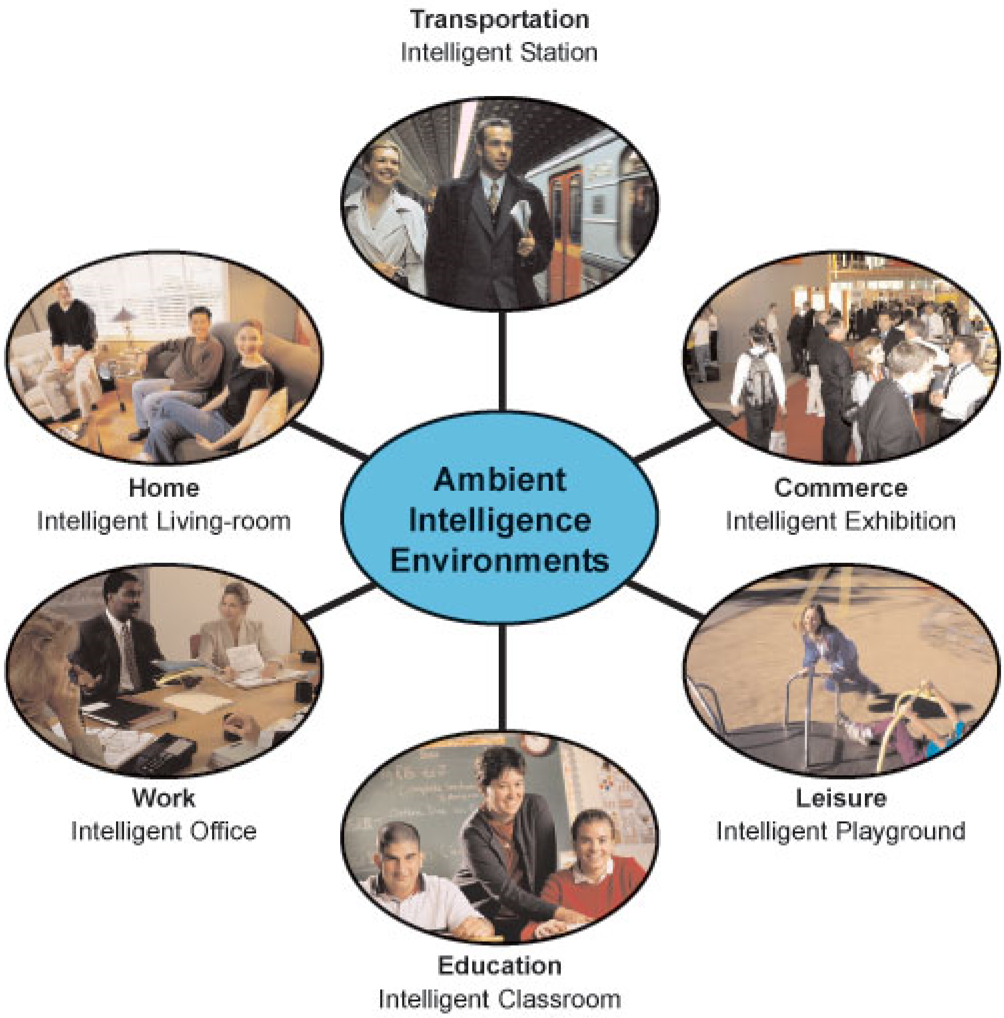


Figure 2: The key thematic areas in the context of AmI

Each thematic area will be equipped with basic AmI infrastructure components (e.g., sensors, actuators, screens, speakers, networks), as well as with special-purpose equipment required for the specific simulated environment, supported user activities and deployment scenarios (e.g., home electronics and healthcare equipment for the home). Additionally, a control center will be created, which will incorporate all the necessary equipment (e.g., servers and routers, chargers, video recorders) to effectively operate and monitor all the thematic areas. A structural representation of the AmI Laboratory is depicted in Figure 3.

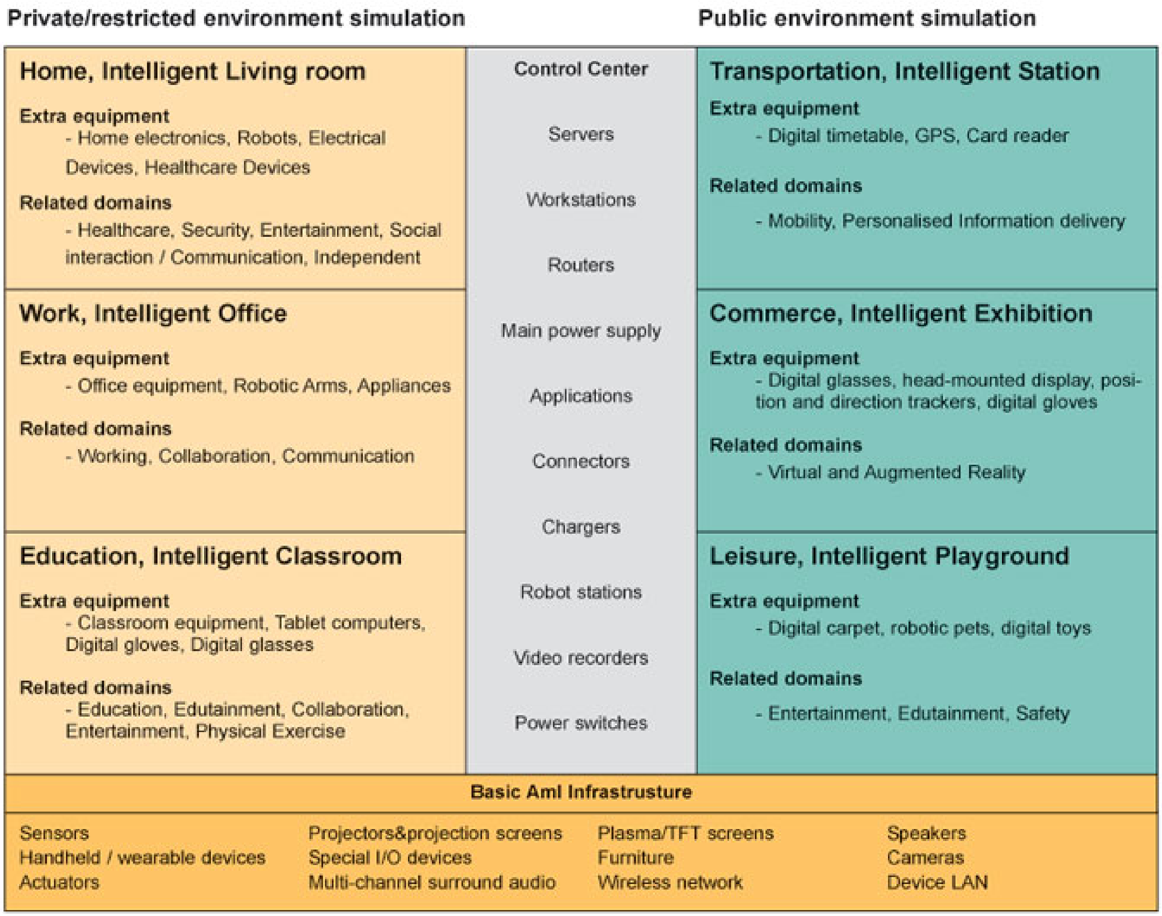


Figure 3: Structural overview of the AmI facility

5.2 The AmI environment and architecture

The architecture of the AmI Facility is depicted in Figure 4 [15]. Such an environment includes many devices, such as PDAs, projectors, monitors, computers, cameras and sensors that need to communicate with each other. The Middleware is the AmI environment's layer that is responsible for communication. The devices are activated depending on external measurements indicated by the sensors. These measurements are processed by the Decision Engine, which is considered as the “brain” of the AmI Environment and defines the state of the environment.

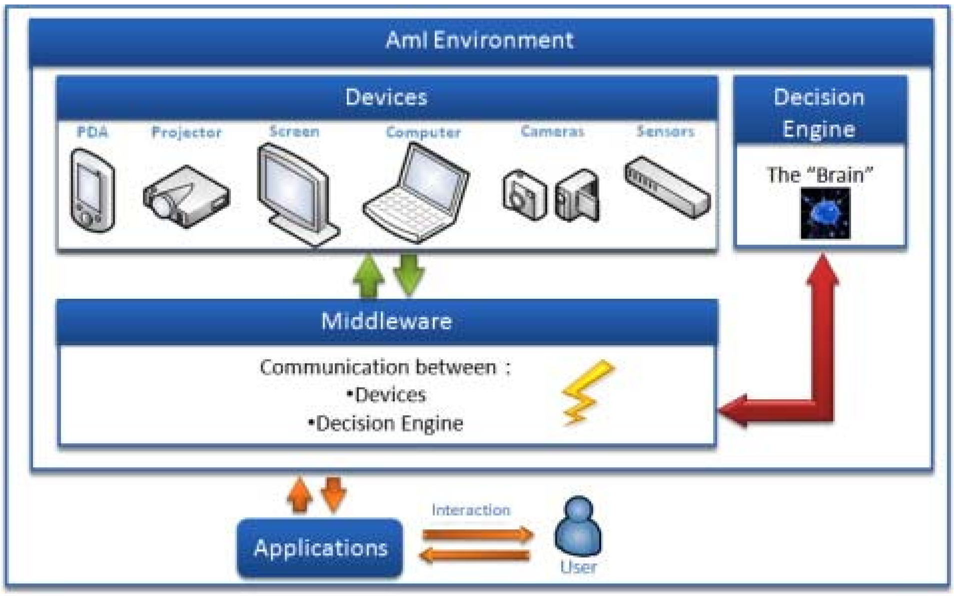


Figure 4: AmI Facility architecture

Currently, the following activities are being conducted:

(a) Design, implementation and evaluation of an integrated, scalable approach towards the creation of AmI environments.

(b) Design of the simulation spaces and selection of the required hardware and software technologies.

(c) Installation, integration and testing of candidate AmI technologies in the AmI Sandbox.

(d) Definition of alternative representative scenarios of use for all the simulation spaces of an AmI Facility, including the home environment.

The following technologies have already been installed in the AmI Sandbox:

- Computer vision system, comprising 8 cameras
- Surround speaker system with 8 speakers
- Various computer-operated lights (neon, spot lights, floor and desk lamps) using both the DMX and X10 protocols
- Computer-operated air-condition
- Various screens and high definition TVs, including touch screens
- One large front projection screen created by 2 ceiling-mounted short-throw projectors
- One back projection screen
- Several sensors (distance, temperature, etc.) and actuators
- Desktop and mobile RFID readers
- An interactive table
- Access control systems
- Positioning system through wireless access points
- Various robotic systems

Based on these technologies, the various laboratories of ICS-FORTH, taking advantage of their related expertise and know-how, are currently working towards the development of several interoperating AmI components, such as:

- AmI software and hardware architectures

- Middleware
- Computer vision subsystem for multiple user localization and gesture recognition
- Speech recognition and speaker localization
- Environment sensing technologies and sensor fusion
- Dynamic surround sound playing system
- Environmental control
- Context management and reasoning
- Access control, information and communications security
- Seamless and intuitive user-environment interaction

The above components are to comprise a generic set of “building blocks” that will be employed to synthesize a wide range of AmI applications. The results of the interaction of such different AmI components will be studied in depth and, depending on their utility and impact, are “propagated” to the ICS-FORTH Ambient Intelligence Facility, that is currently being built and that will occupy a three-floor 3,000 square meters building, comprising simulated AmI-augmented environments and their support spaces (e.g., computer and observation rooms), laboratory spaces for developing and testing related technologies, staff offices and public spaces.

6. The REACTION Software Development Kit

According to the Description of Work all parts of the REACTION platform will be installed and integrated in the AmI test bed of FORTH-ICS so that they are tested and the technical environment is demonstrated before being ported to the field trials. This installation requires a middle layer of interoperability between the AmI environment and the Hydra Software Development Kit that will be used for the implementation of the REACTION platform. FORTH-ICS is committed to build such an “integration bridge” between the two platforms with their own resources and outside of the context of the project in due time and after a certain level of familiarity with the Hydra SDK has been gained.

In the following paragraphs a high level description of the Hydra middleware is provided.

6.1 The HYDRA Project

The aim of the Hydra project was to research, develop, and validate middleware for networked embedded systems that allows developers to develop cost-effective, high-performance ambient intelligence applications for heterogeneous physical devices.

The first objective was to develop middleware based on a Service-oriented Architecture (SoA), which makes the underlying communication layers transparent to the applications built on top of the middleware. The middleware includes support for distributed as well as centralised architectures, security and trust, reflective properties and model-driven development of applications.

The Hydra middleware is deployable on both new and existing networks of distributed wireless and wired devices, which operate with limited resources in terms of computing power, energy and memory usage. It allows for secure, trustworthy, and fault tolerant applications through the use of novel distributed security and social trust components.

The embedded and mobile Service-oriented Architecture provides interoperable access to data, information and knowledge across heterogeneous platforms, including web services, and supports true ambient intelligence for ubiquitous networked devices.

The second objective of the Hydra project was to develop an Integrated Development Environment (IDE), including a Software Development Kit (SDK) and a Device Development Kit (DDK). The IDE can be used by developers to develop innovative semantic model driven applications with embedded ambient intelligence using the Hydra middleware.

6.2 Architecture

Hydra applications are based on networks of embedded devices, which may be geographically distributed and possibly heterogeneous in the technologies supported.

The Hydra Model-Driven Architecture (MDA) supports the design and run-time of such applications by providing a set of models, transformations and component assemblies.

The objectives are to facilitate programming with devices for application developers to thru the Hydra SDK, and for device manufacturers to Hydra enable physical devices through the Hydra DDK. The semantic model-driven architecture of Hydra is based on a combination of ontologies and other semantic web technologies to support the design of applications of device networks in different application domains. The MDA is both a design-time and a run-time resource.

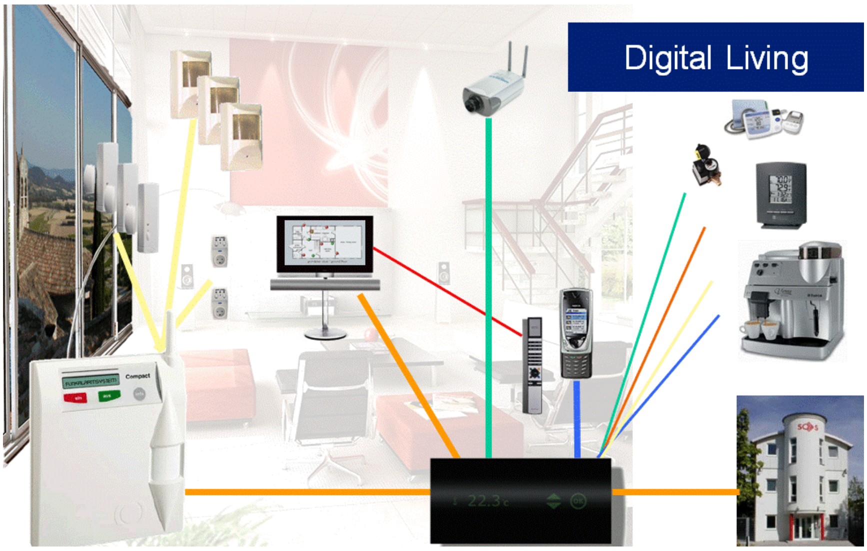


Figure 5: Device networks for home automation may include large numbers of heterogeneous devices.

Even though Hydra is a middleware and the MDA is a part of the middleware, the platform has been tested in three different application domains: home automation, eHealth and agriculture.

Various types of devices usable in these domains have been the sources for requirements on the semantic representations of device and service descriptions and development support and tools for programmers.

Recent developments in home automation has resulted in new types of home appliances that are DLNA-compatible (a further development of UPnP), current mainly various media management devices. These devices should be able to coexist in a Hydra network, with other types of sensors and actuators based on various wireless technologies like ZigBee, Bluetooth and RF, which are supported by Hydra.


Figure 6: Devices for home health-care and remote monitoring

In the areas of health and agriculture, Hydra is supporting the use of various monitoring and sensor devices, for vital signs monitoring and environment sensors.

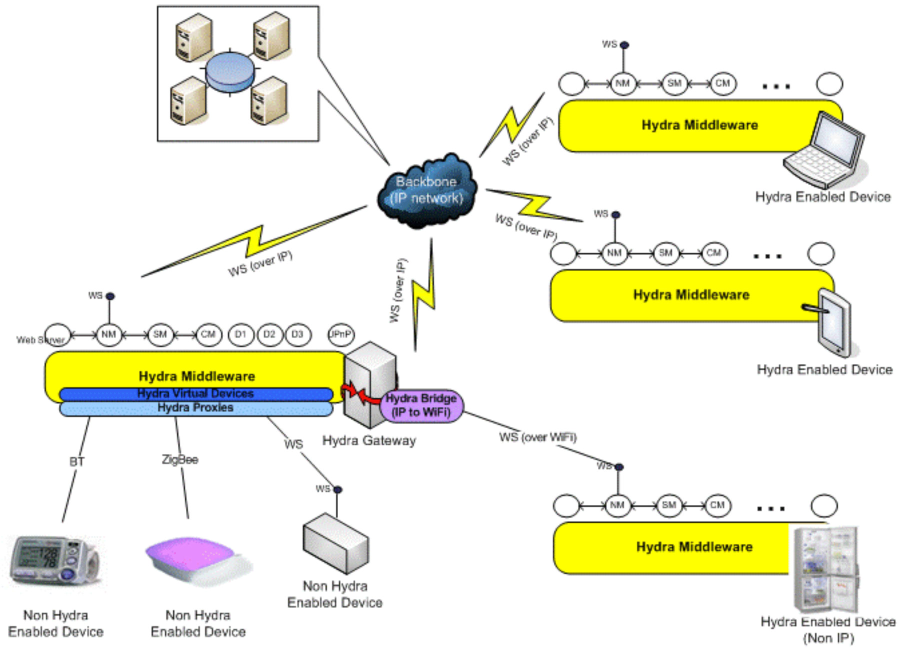


Figure 7: The Hydra middleware implementing Hydra Device networks

In order to connect these different devices, Hydra implements the necessary network platform infrastructure (based on SOA over P2P). On top of this platform the MDA provides the tools and mechanisms allowing programmers to develop model driven applications with the above mentioned device types.

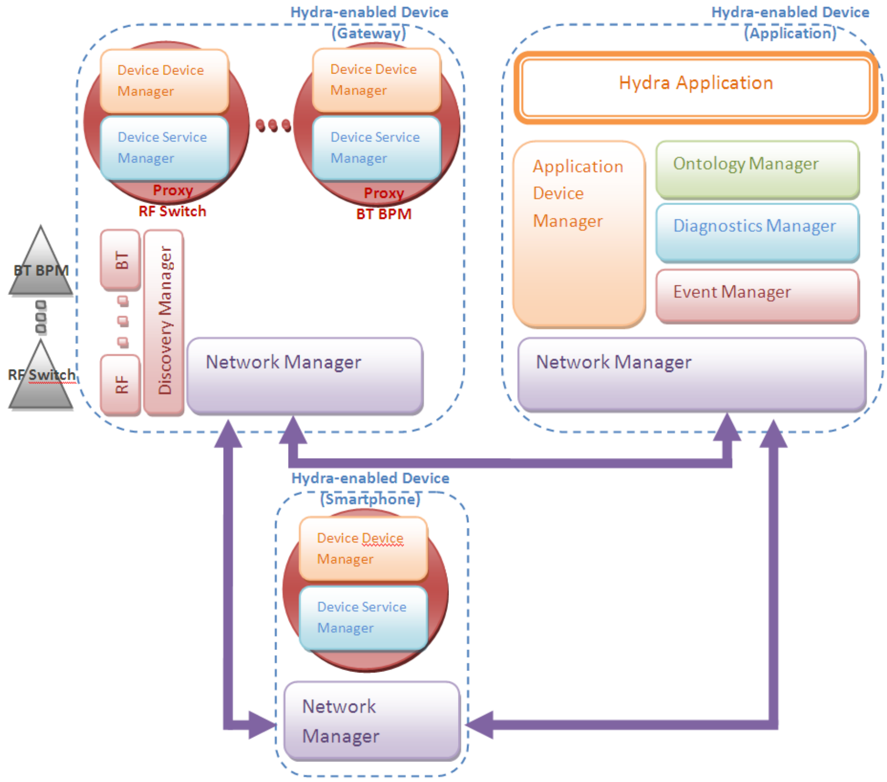


Figure 8: HYDRA Middleware Managers deployed

The HYDRA platform consists of a set of software components, referred to as HYDRA Managers, which can be configured in different ways in order to meet varying network and applications requirements.

6.3 Devices in HYDRA

A basic idea in Hydra is to differentiate between the physical devices and the application´s view of the device, in terms of so called Hydra Devices.

6.3.1 Physical Devices and Hydra Devices

A Hydra Device is the software representation of a physical device. This representation is either implemented by a proxy running on a gateway device, or, by embedded Hydra managers on the actual device. A Hydra Device is said to Hydra-enable a physical device.

The MDA run-time includes a Device Service Generator which creates the service interfaces for discovered devices. Each Hydra device will thus get a web service as well as a UPnP service interface.

There are five categories of Web (UPnP) services generated for a Hydra Device,

- A Generic Hydra web service, exposing metadata and management functions common to all Hydra Devices
- An Energy web service, providing a set of functions for the monitoring and control of energy consumption of devices.
- A Memory Service which allows logging and storing of device internal data such as state variables and energy consumption data.
- A Location Service which can be used to query the device about is location and position.
- A device type specific web service, exposing the device type specific functions

6.3.2 Device Ontology

In Hydra, ontologies are used to model devices, security requirements and parts of the middleware itself.

All Devices in HYDRA have a semantic description, which is maintained in the HYDRA Device Ontology. The Hydra Device Ontology presents the high level concepts describing basic device related information, which will be used in both development and run-time process. The basic ontology is composed of several partial models representing specific subsets of device information.

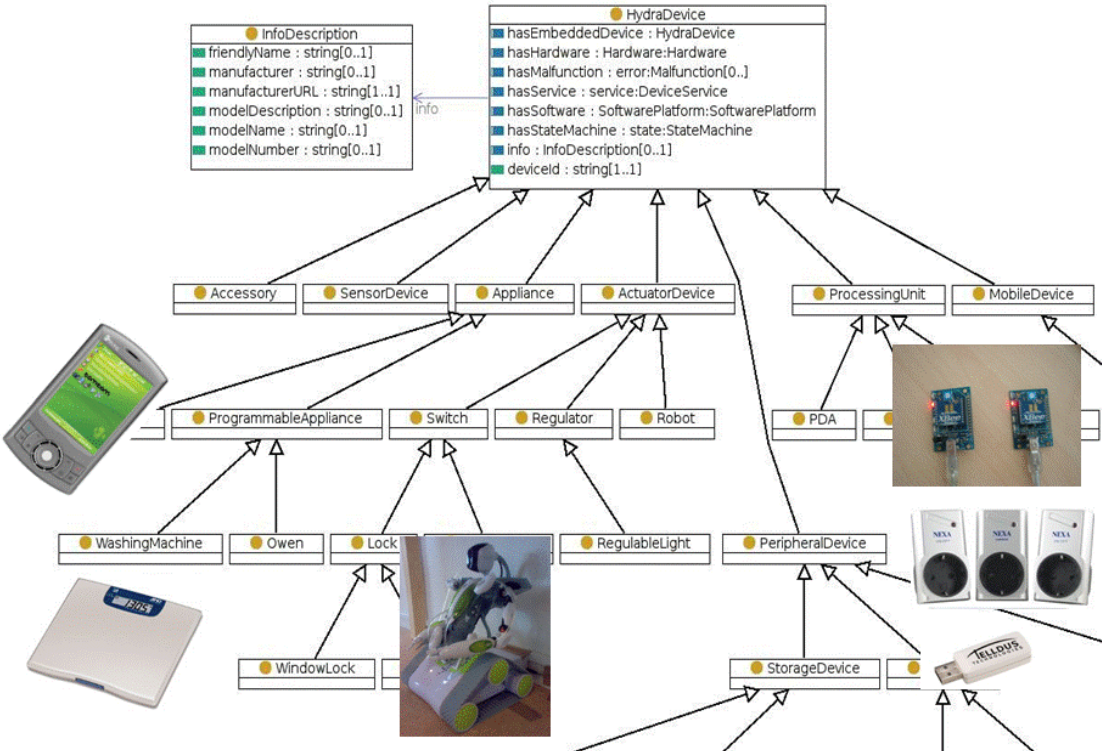


Figure 9: Device taxonomy subset of the Hydra Device Ontology

The device ontology is divided into four interconnected modules:

- Basic device information and taxonomy
- Device services
- Device malfunctions
- Device SW and HW capabilities and state machine

The Device Ontology plays a role both in design time, supporting application developers,

- to visualise available devices and their services, connected to a Device Application Catalogue (DAC)
- to generate software web service interfaces for devices

and in run-time primarily in supporting the devices discovery process.

6.3.3 Semantic Devices

Based on Hydra Devices, we introduce the concept of *Semantic Devices* as a programming construct. This allows a programmer to develop new applications specific adaptations of the available Hydra Devices. The Hydra Devices offers a set of services, a lamp might offer "on/off" and "dimming" as two services while a pump might offer "increase flow" and "get water temperature" as two services.

The services offered by the physical devices have been designed independently of particular applications in which the device might be used. A semantic device on the other hand represents what the particular application would like to have. For instance, when we are designing the lighting system for a building it would be more appropriate to model the application as working with a logical lighting system that provides services like "working light", "presentation light", and "comfort light" rather than working with a set of independent lamps that can be turned on/off. These logical devices might in fact consist of aggregates of physical devices, and use different devices to deliver the service depending on the situation. The service "Working light" might be achieved during daytime by pulling up the blind (if it is down) and during evening by turning of a lamp (blind and lamp being Hydra Devices).

6.4 Device Discovery

An important aspect of all ambient intelligence applications is for users, applications and devices to quickly and easily discover devices that are available in the vicinity. The first issue is to discover the existence of a device that one can communicate with, the second issue is to discover what type services the device offers and thirdly to discover how to access and execute these services.

The overall discovery approach in Hydra is based on the combination of UPnP for networked devices with semantic services, allowing UPnP-enabled devices to act as semantic web services towards the network. We are using a layered approach to discovery, handling discovery at three layers: *physical*, *network* and *semantic*.

The discovery process operates both locally and remotely, so that devices that are discovered in a local Hydra network can also be discovered in a peer Hydra network over the P2P protocol implemented by the Hydra Network Manager.

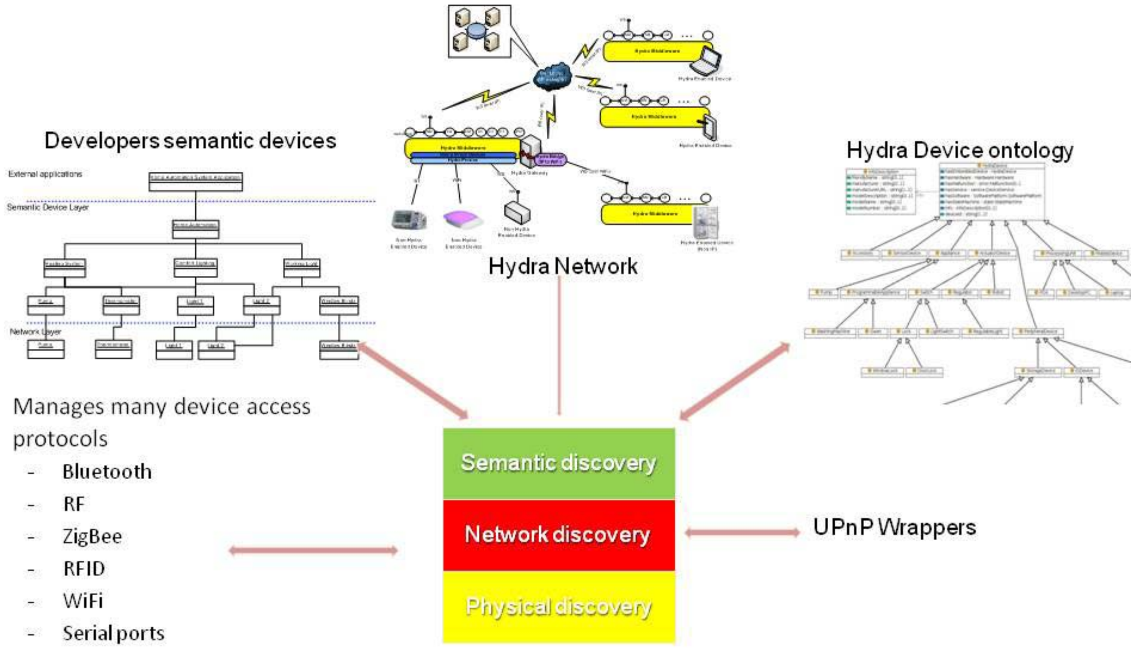


Figure 10: The 3-layered Discovery Architecture is part of the Hydra MDA.

The lowest discovery layer implements the protocol specific discovery of physical devices. This is performed by a set of specialized discovery managers listening for new devices at gateways in a Hydra network. The second layer uses UPnP/DLNA technology to announce discovered physical devices in the local network and to peer networks.

At the top most layer the device type is resolved against the Device Ontology and is mapped to some Hydra Device type. It is then placed in the *Device Application Catalogue* (DAC). If an application subscribes to events regarding this type of device, it will be notified that the device is available and has been placed in the Device Application Catalogue.

6.5 Network architecture

6.5.1 Network Manager: Building a P2P overlay network

The main objective of the HYDRA network architecture is to interconnect different Hydra Enabled Devices in local and remote networks. A main problem here is that devices may be hidden in Local Area Networks, behind firewalls, routers and Network Addressing Translators (NATs), so it would be difficult to interconnect the devices.

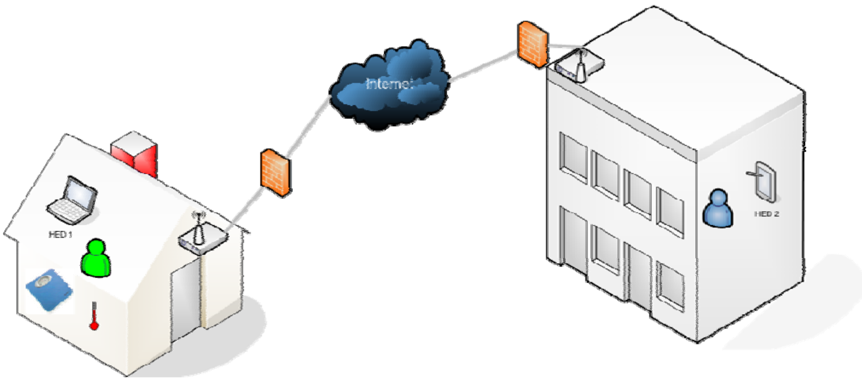


Figure 11: Hydra uses P2P and Tunnelling for bridging local networks

However, the HYDRA Network Manager solves this problem by using P2P technology together with SOAP tunnelling techniques independently of the network addressing and protocols. This allows for communication and access between devices that are in two different networks, for instance between the office and the home. The Network Manager (and its sub-manager the Backbone Manager) solves this problem by building an overlay Hydra network, independently of the network addressing and protocols.

The Backbone Manager, relies on JXTA P2P platform in order to build the overlay network. JXTA is a set of open, generalised P2P protocols enabling any connected device on the network to communicate and collaborate. Using the JXTA protocols, HEDs are directly connected even if they are connected in different networks separated by firewalls or NATs.

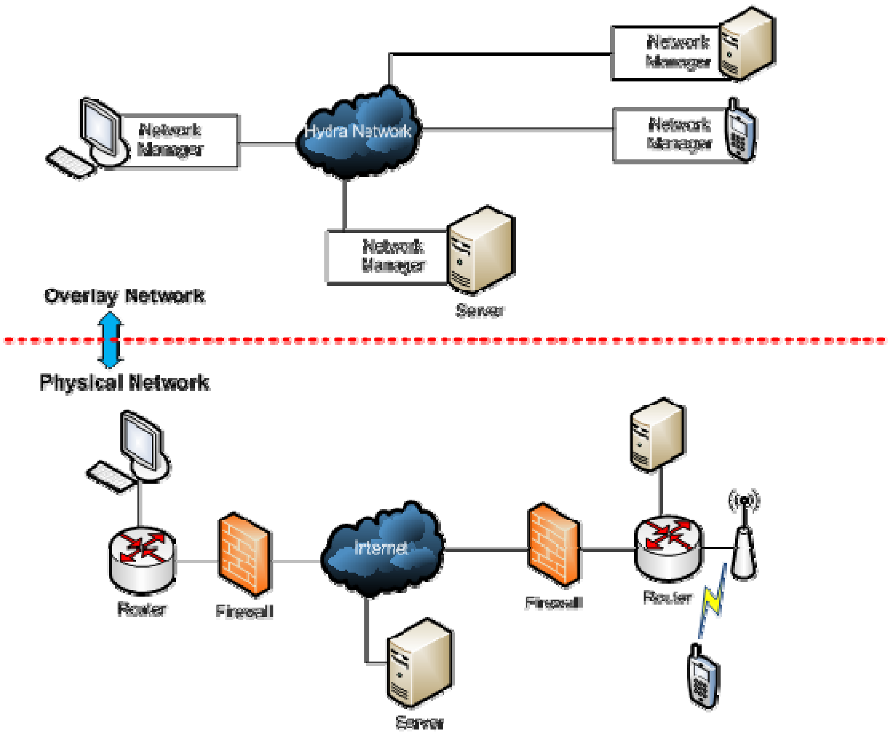


Figure 12: Overlay network for Hydra

6.5.2 HID propagation

From the middleware point of view, a Hydra Identifier (HID) based addressing method has been defined for Hydra, instead of the usual IP based one. The responsible of managing these HIDs is the HID Manager. Its main functionality is providing a unique context dependent identifier for every device (physical or virtual), resource or service, called HID. It is also responsible of maintaining the idTable, a data structure dedicated to store the matching between logical and physical identifiers.

However, this addressing is useless if there is not a way to propagate this information to other HEDs involved in the Hydra Network. The Backbone Manager is responsible of spreading this information between the different HEDs in the Network. Thus, every HID Manager belonging to the Hydra Network keeps inside idTable and an updated list of every HID in the network. This process is known as Network Manager Discovery.

6.5.3 SOAP Tunnelling Approach for Device Communication

As the Hydra architecture is service-oriented, where web-services (WS) is the technology used to implement it, the communication between applications running in different Hydra-enabled devices will be based on SOAP messages. Usually, SOAP messages are forwarded through TCP connections to the destination. The destination address corresponds to the endpoint contained in the message.

Traditional WS architectures are based on client-server architectures, where the server is an always-on end system with a well known endpoint address, which should be known by clients before hand (using either service descriptors or UDDI registries). The SOAP tunnelling approach proposes a way to replace this client-server architecture for a distributed one, using the Network Manager P2P platform. In this architecture, all the peers will act as clients and servers at the same time. Figure 13 shows an example of a client-server based architecture and the distributed approach.

Furthermore, actual WS communications require direct connection between the client and the server, being impossible to consume services across networks.

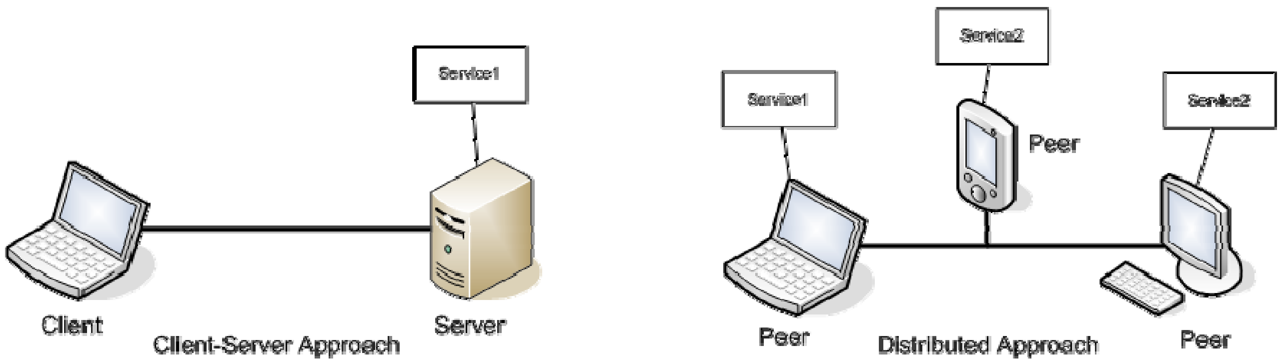


Figure 13: Client-server vs. Distributed approaches

Moreover, in the Hydra middleware, devices are presented as UPnP devices by the Device Manager. But UPnP discovery information is usually restricted to Local Area Networks. Using the SOAP tunnelling the Device Manager will be able to exchange the UPnP information between different Discovery Managers in the Hydra Network. Thus other Device Managers will be able to control UPnP devices located in remote networks using the SOAP technique presented in this section.

Therefore the main objective of the SOAP tunnelling approach is to enable SOAP messages exchange across different networks, being possible to consume services provided by different Hydra Enabled devices or controlling UPnP devices located in different Local Area Networks. An example of the application of SOAP tunnelling is shown below. Thanks to the Network Manager and the SOAP tunnelling approach, HED2 device is able to discover UPnP devices located at home network (weigh scale and thermometer) and to consume the web services offered by the application running on the HED1 device.

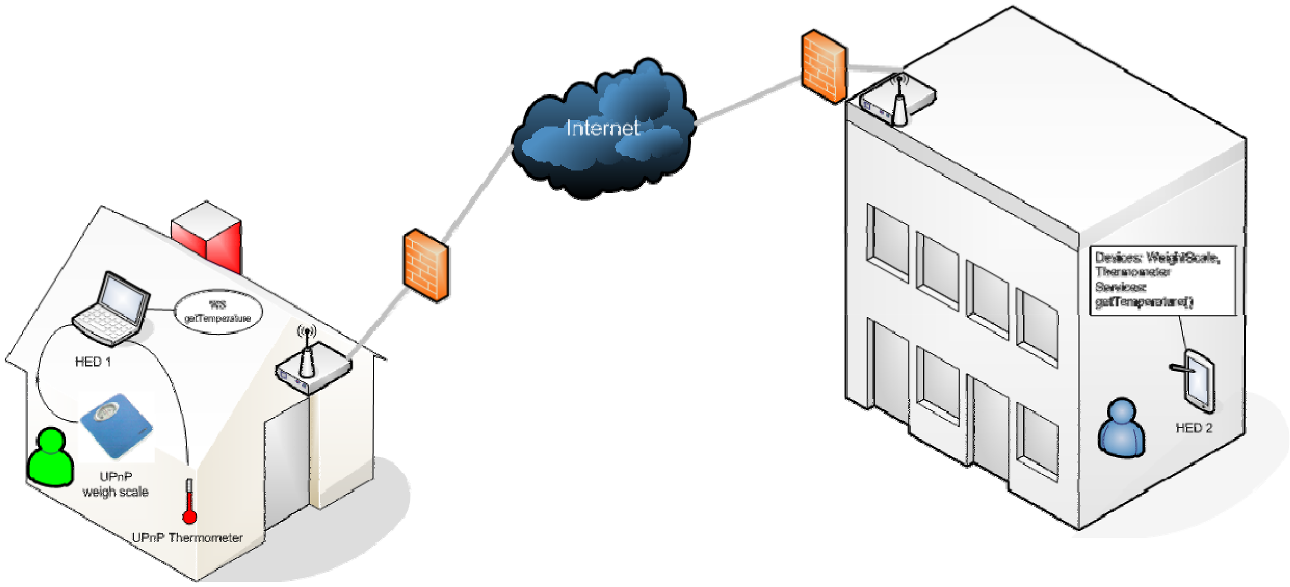


Figure 14: SOAP tunnelling applications example

6.6 Developing HYDRA applications

As mentioned above, Hydra applications are intended to exploit the functionality provided by networks of embedded devices, which may be geographically distributed and possibly heterogeneous in the technologies supported.

6.6.1 The Device Application Catalogue (DAC)

The *Device Application Catalogue* (DAC) is a fundamental part in every Hydra application. It is a runtime component that keeps track of and manages all devices that are currently active within an application. The DAC is managed by the Application Device Manager. The DAC serves all Hydra middleware managers with the information and metadata they need regarding devices, their services, and their status.

The Application Device Manager uses the Hydra Device Ontology and models for discovery to recognise new devices when they enter into a Hydra network. Based on the discovery model it queries the Device Ontology to deduce what type of device has entered the network. The Hydra DAC can be queried by different middleware managers to retrieve a service interface for different devices.

A Hydra browser has been developed to allow a user/developer to graphically browse the Hydra network and inspect properties and services of devices. The browser tool also allows the user to invoke the different services offered by devices. To illustrate the functionality of the Device Application Catalogue we can view the figure below that shows the *Hydra DAC Browser* which allows browsing of the different devices that have currently been discovered by the Hydra DAC.

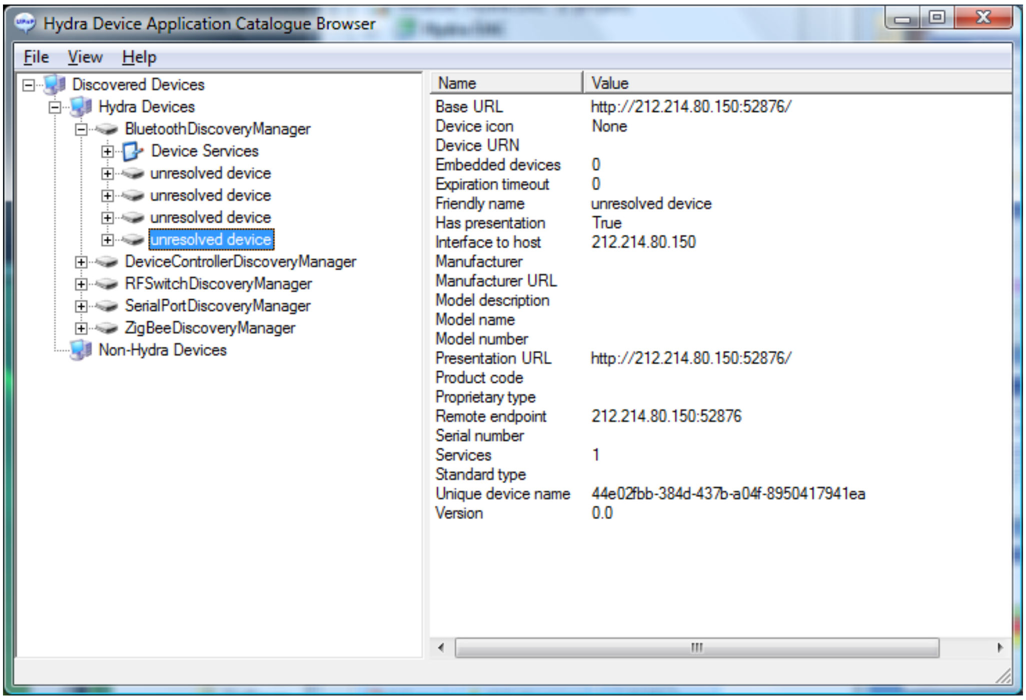


Figure 15: The Hydra DAC Browser

The Hydra DAC uses the Hydra Device Ontology and models for discovery to recognise new devices when they enter into a Hydra network. Based on the discovery model it queries the Device Ontology to deduce what type of device has entered the network. The Hydra DAC can be queried by different middleware managers to retrieve a service interface for different devices.

6.6.2 The SDK and DDK

The SDK provides a collection of templates, classes and browser tools for development of Hydra applications. The SDK, and the DDK, are intended as integrated components in the Hydra IDE, to be instantiated on two available platforms (.net Visual Studio and Eclipse).

The chosen way of integration is by means of templates and by embedding selected tools.

Application Project Templates

The project templates for Visual Studio gives the developer a way of creating a Hydra application without having to write the boiler plate code necessary to set up the environment and finding the end points for interacting with Hydra managers.

There are a number of templates available which cater for some typical development scenarios. The basic difference between templates is which managers are directly available and which boiler plate code examples are provided. Among these are a number of application templates,

- Basic Application: most generic type of application, minimal.
- Energy Application: monitoring and control of a set of homogeneous devices in a local network.
- Dynamic Application: a generic application using devices of a certain class at run-time, i.e., not bound to specific devices types by design time.
- Sensor Application: a generic event-based application.

The templates are all integrated in the host IDE.

All metadata and the state of a HYDRA device ARE communicated using an XML structure, The Hydra Device XML. This is an extension of the UPnP SCPD XML (Service Control Point Document) vocabulary.

The SDK Class library contains a number of ready-to-use Hydra Devices Types with corresponding web services, which are available to developers.

6.6.3 HYDRA enabling a device using the .Net DDK tools

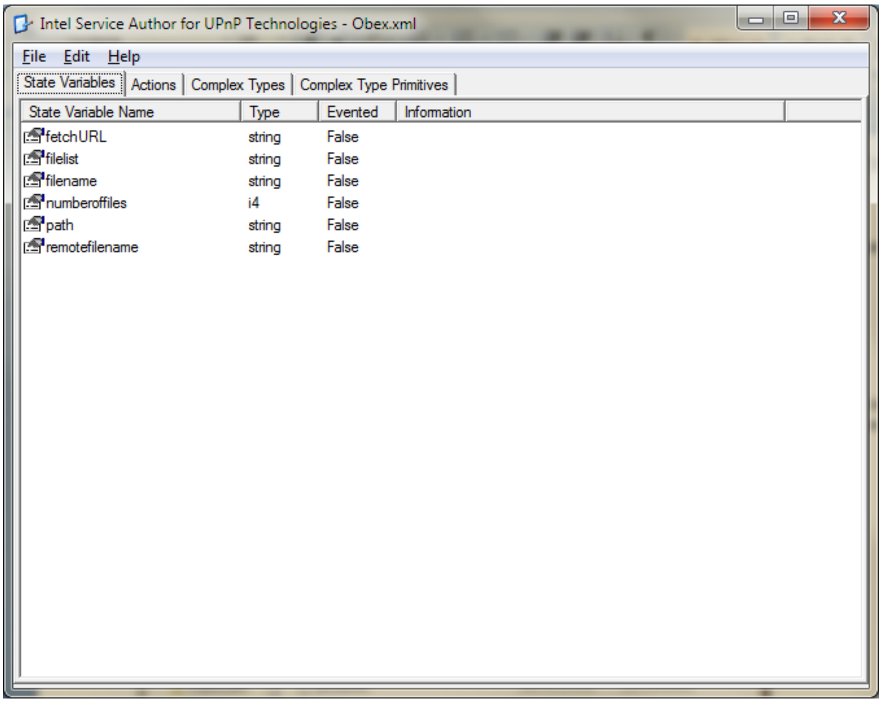
Whereas the SDK is focused on the development of applications of devices, the purpose of DDK is to adapt various physical devices for use by Hydra developers.

There are two main tools for creating device code for .Net in Hydra:

- Intel Service Author for UPnP Technologies
- Hydra .Net DDK tool

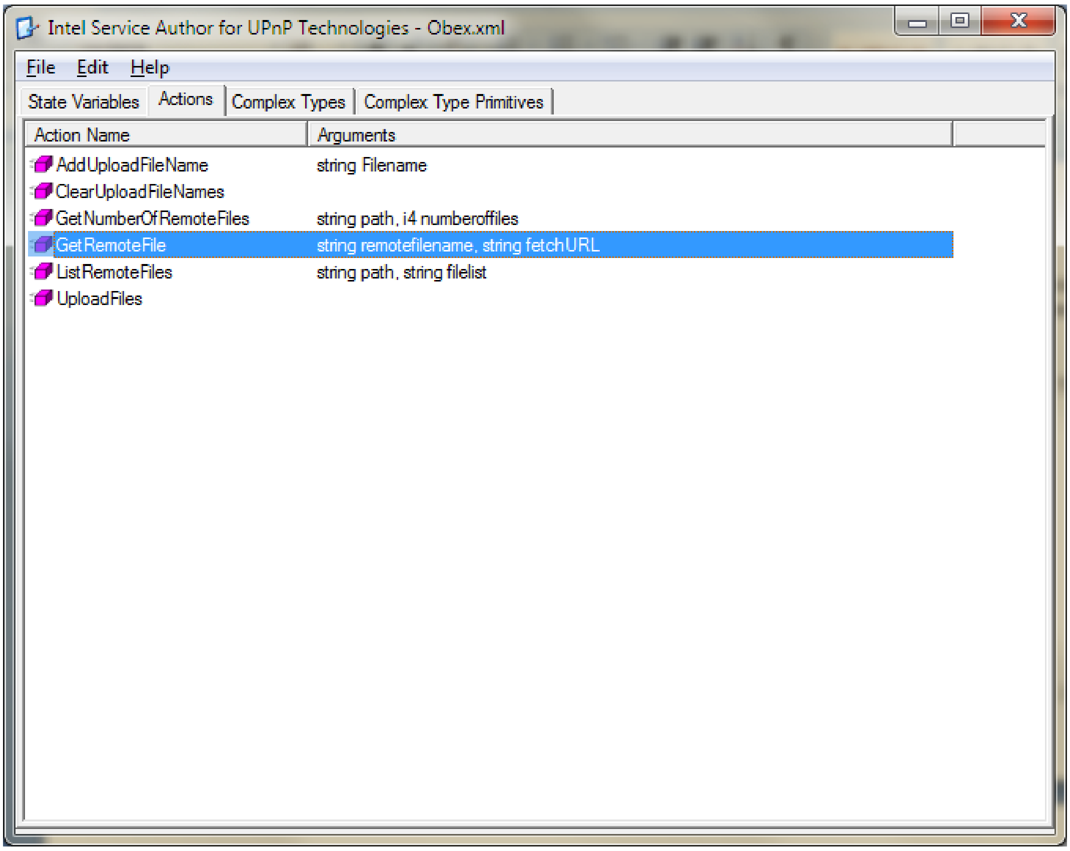
Using Intel Service Author for UPnP Technologies

This tool is used for creating the service methods and producing an SCPD file that will be used as input for the final code generation.

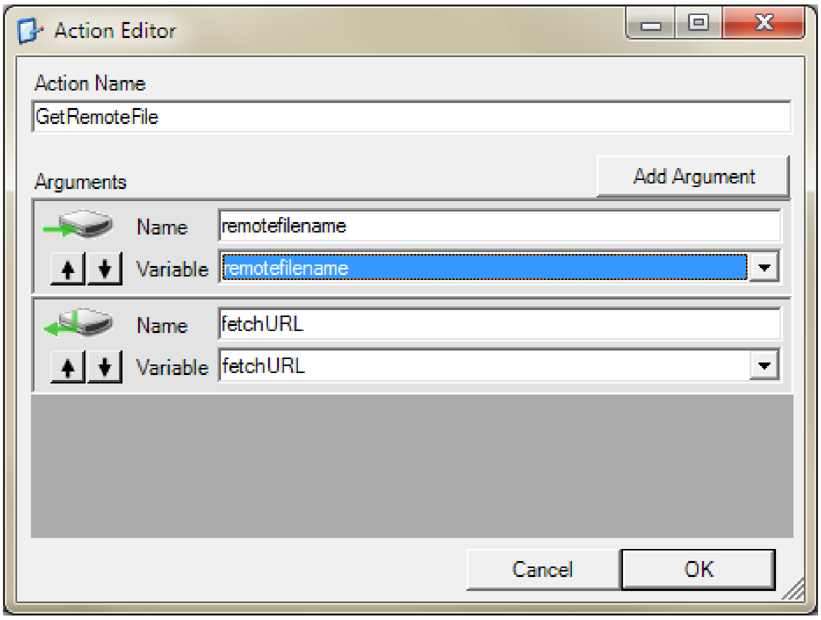


The first step is to define the state variables that will be used by the service. State variables have to be defined for all Input/output parameters used in the service. In this case we have a number of state variables defined with their respective types.

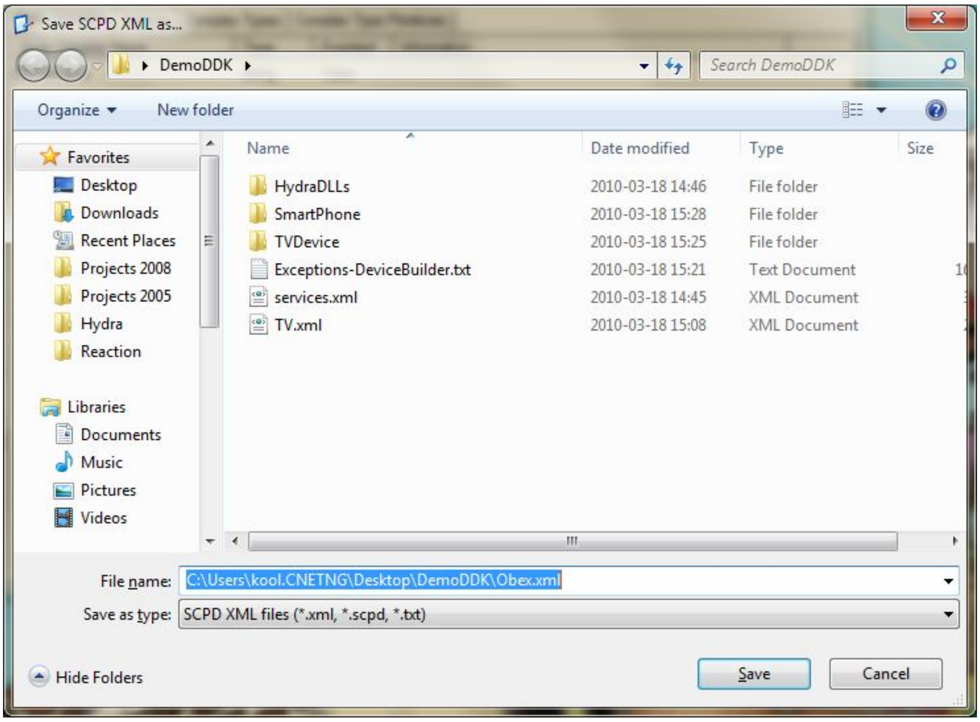
The next step is to define actions, i.e. the methods that this service should support. This is done in the "Actions" tab.



Here we have defined a number of methods with their corresponding arguments. The methods are added using the “Action Editor” which allows for adding arguments and defining in which direction it is used, see below.



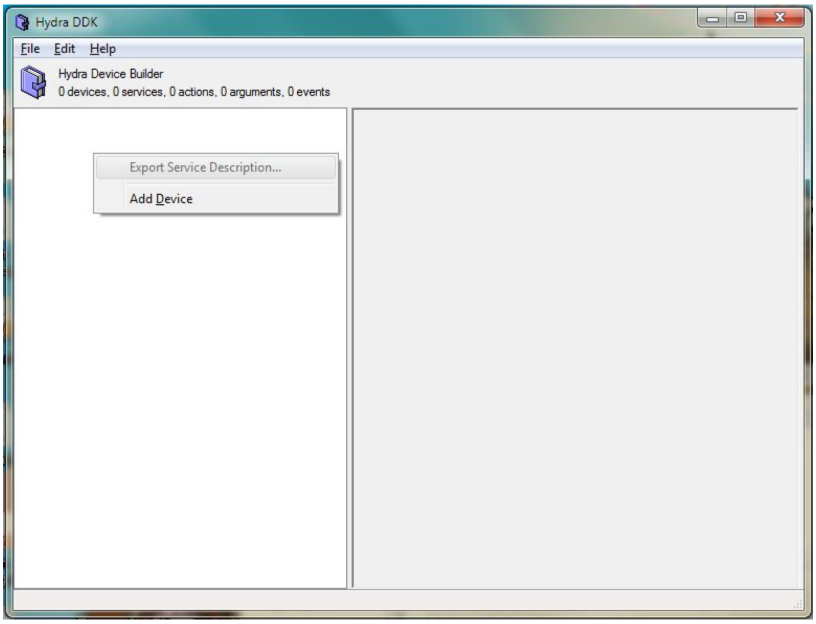
When one is finished it is time to save the SCPD to file for later processing in the Hydra .net DDK tool.



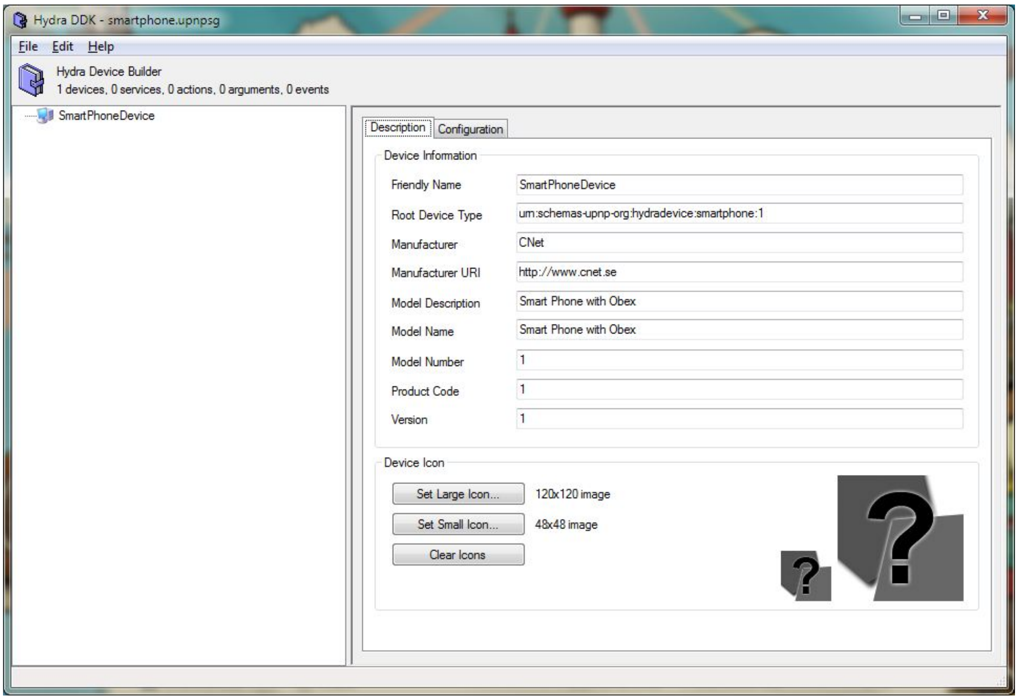
Using Hydra .Net DDK tool

The actual code generation is done in the Hydra .Net DDK tool. It is also where the actual configuration of device type and other settings are done.

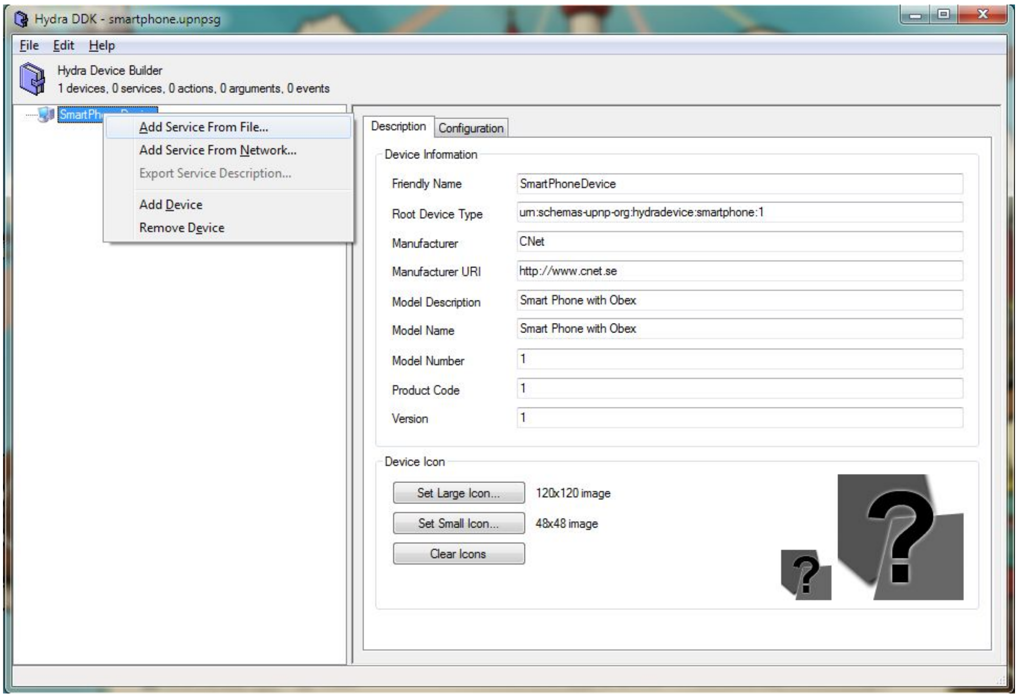
The first step is to “Add Device” by right clicking in the tools left pane.

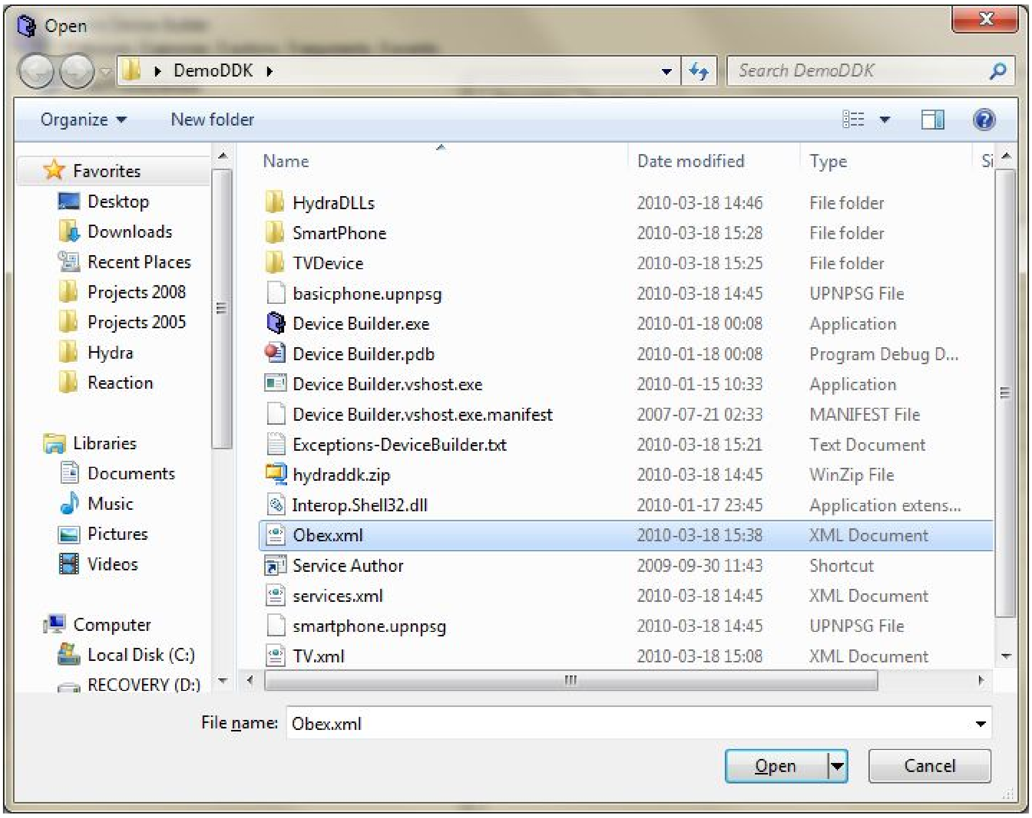


The next step is to edit the meta data for the device, i.e., device name, type, description etc.

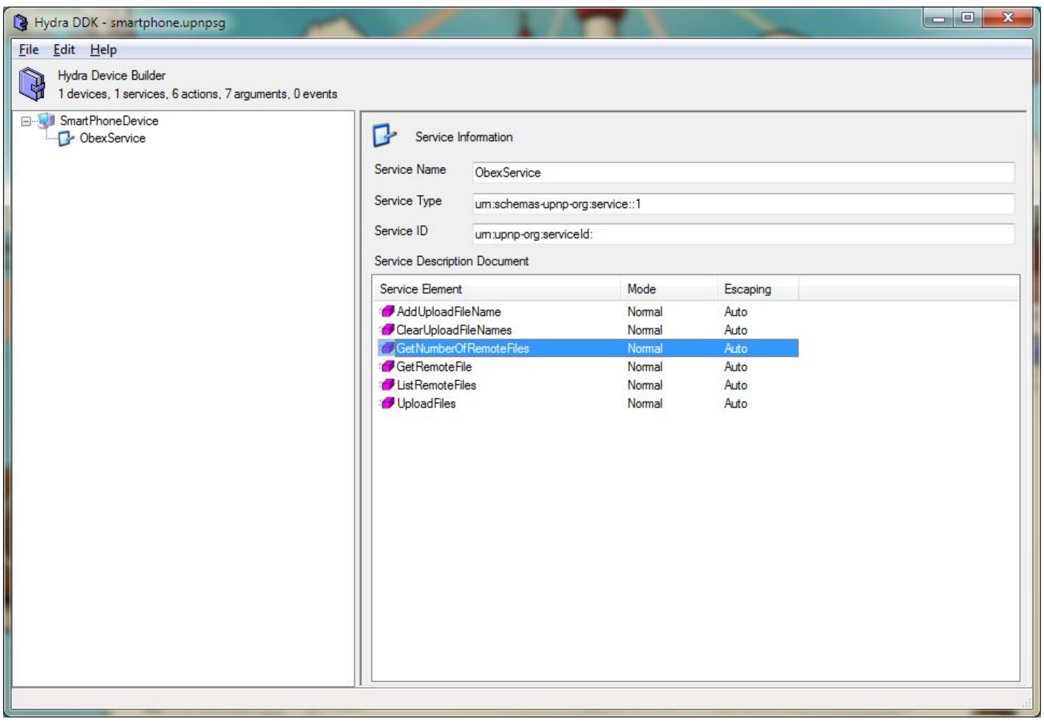


Then one adds the service created in the previous section by right clicking on the device in the left pane.

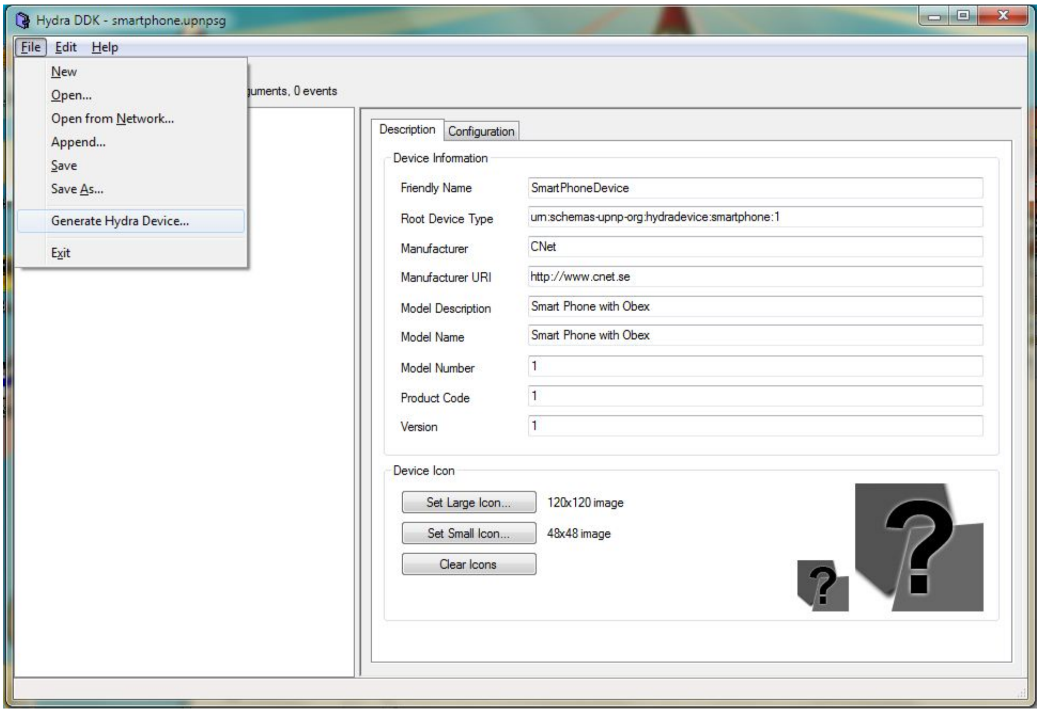




Now we have added the OBEX service and we can see all the methods in that service.



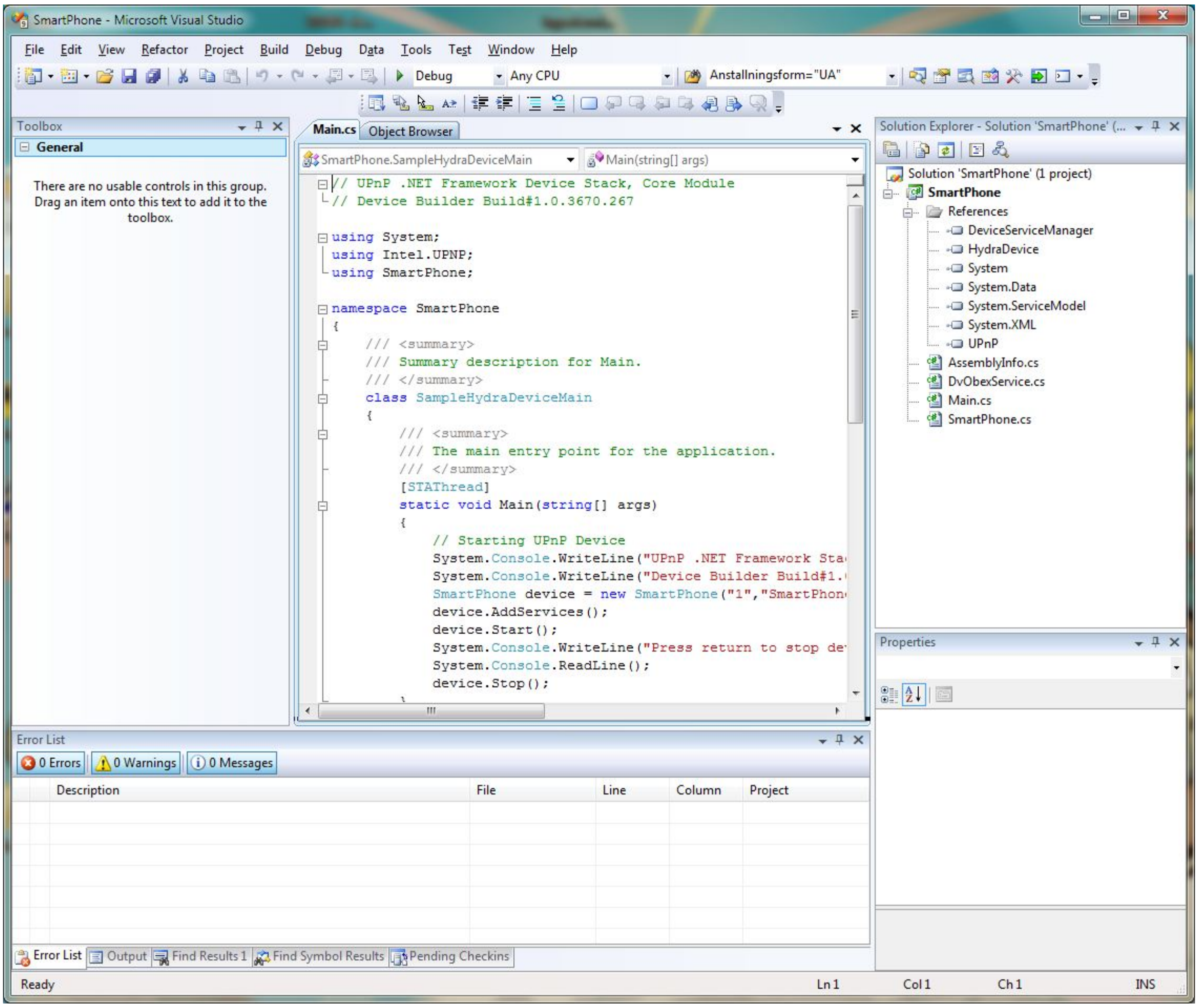
Finally we have arrived at the stage where it is time to generate the code for the Hydra device. Select the "File" menu and choose "Generate Hydra Device".



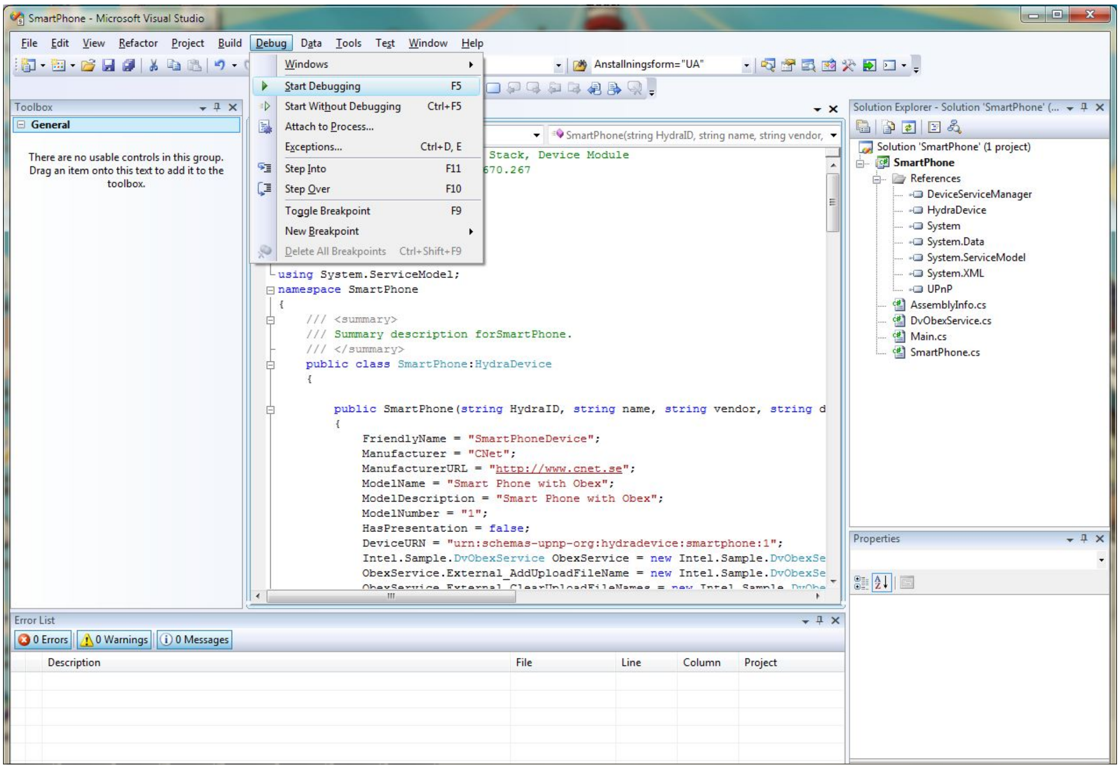
In the code generation dialogue one has to decide the project name and optional Namespace for the generated code.

A complete Visual Studio project is created with the necessary Hydra references.

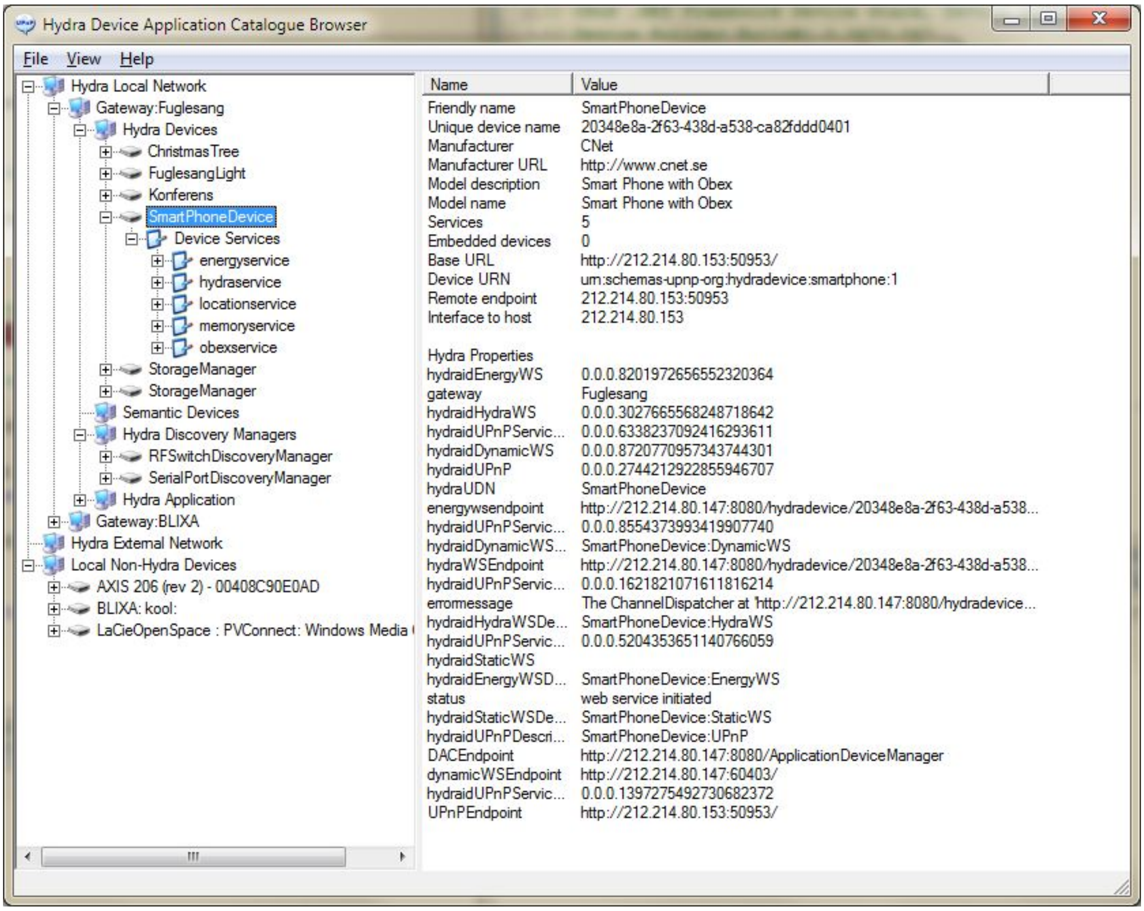
The next step is to open the Visual Studio project.



The device code is already runable since all methods are stubbed. Normally one would then change the code in the stubs to do the actual device communication. The location of the stubs to be changed is in “Device name”.cs, i.e. SmartPhone.cs in this project. But in this case we will start the device by opening the “Debug” menu and selecting “Start debugging”.



If we run a Hydra DAC tool we will find our newly created device with all its services. Note that we have automatically received the relevant Hydra services: HydraService, EnergyService, LocationService and Memory service. We can also see that the Device is properly discovered and has all the Hydra properties such as HID.



7. Conclusions

Throughout their history, humans had to continuously adapt themselves to their surrounding environment, in order to survive, but also make the best out of it. Today, Ambient Intelligence (AmI) technologies have the potential to change this status quo through the creation of "intelligent" environments able to proactively adapt to humans, as well as serve their needs and goals, in the best possible way. In this context, our vision is to improve the quality of life of all citizens of the emerging Information Society through the creation and provision of safe, efficient and user-friendly AmI technologies, which support and cater to the needs of each and every individual user in a seamless, unobtrusive and invisible way.

Ambient Intelligence (AmI) presents a vision of tomorrow where 'intelligent' environments react in an attentive, adaptive and active (sometimes proactive) way to the presence and activities of humans and objects in order to provide appropriate services to the inhabitants of these environments. It is an emerging field of research and development that is rapidly gaining wide attention from an increasing number of researchers and practitioners worldwide, particularly in Europe.

Ambient Intelligence technologies integrate sensing capabilities, processing power, reasoning mechanisms, networking facilities, applications and services, digital content and actuating capabilities distributed in the surrounding environment. While a wide variety of different technologies is involved, the goal of Ambient Intelligence is to either entirely hide their presence from users or to smoothly integrate them in their surroundings as enhanced environment artifacts rather than technological gadgets. This way, the computing-oriented connotation of technology essentially fades out or even disappears in the environment, providing seamless and unobtrusive interaction paradigms. Therefore, people and their social situation, ranging from individuals to groups, be they work groups, families or friends and their corresponding environments (office buildings, homes, public spaces, etc) are at the centre of the design considerations.

Ambient Intelligence brings a special perspective to the on-going research associated with technical fields like ubiquitous computing, pervasive and proactive computing, ambient computing, embedded computing, and smart objects. Ambient Intelligence has become well-focused by putting people and social contexts at the centre, while at the same time aiming to distribute, embed, coordinate and interactively deliver computing intelligence within the surrounding environment. The notion of Ambient Intelligence, as described above, is becoming a de facto key dimension of the emerging Information Society, since many of the new generation industrial digital products and services are clearly shifted towards an overall intelligent computing environment.

We foresee that the Ambient Intelligence will provide the technological foundation for delivering enhanced healthcare solutions to specific patient groups such as the ones with diabetes. Therefore the AmI vision is important and high relevant to the work and results that the REACTION project aims to deliver.

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